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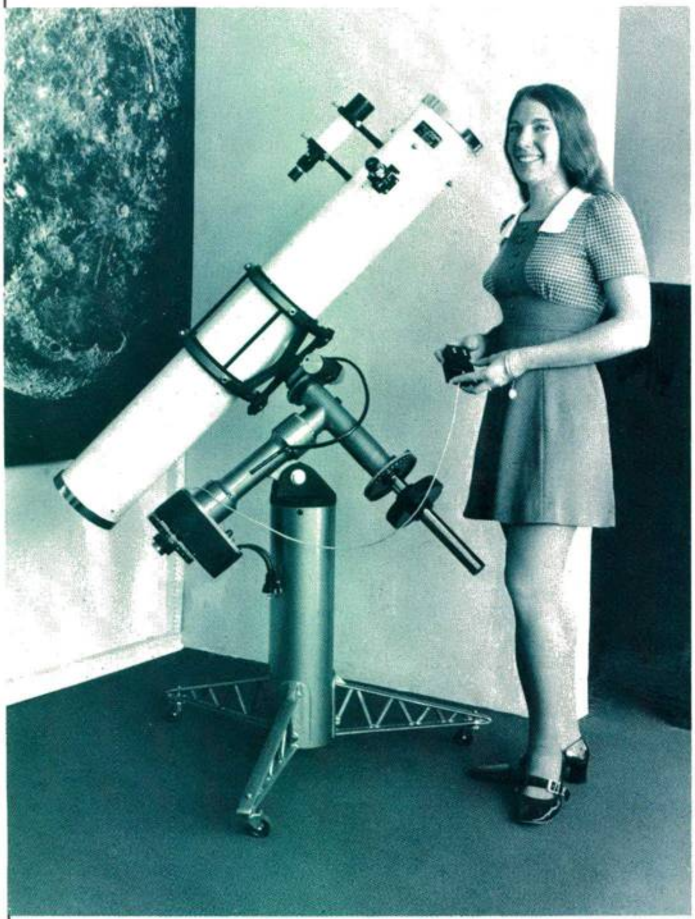

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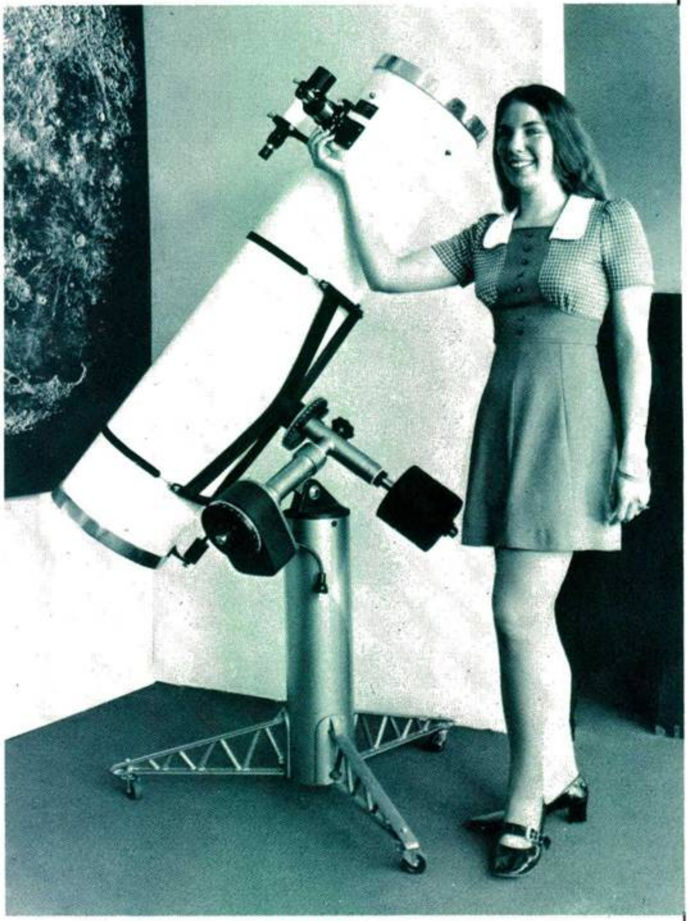

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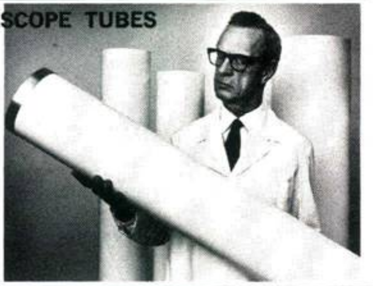

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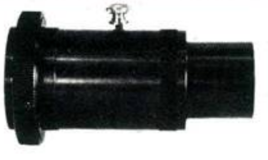

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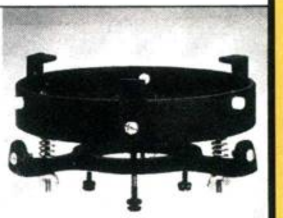

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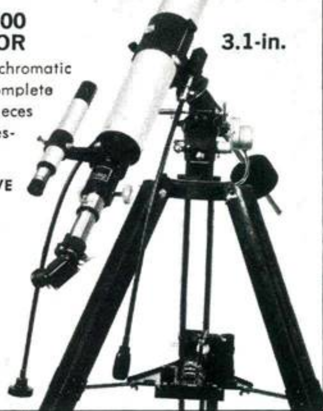

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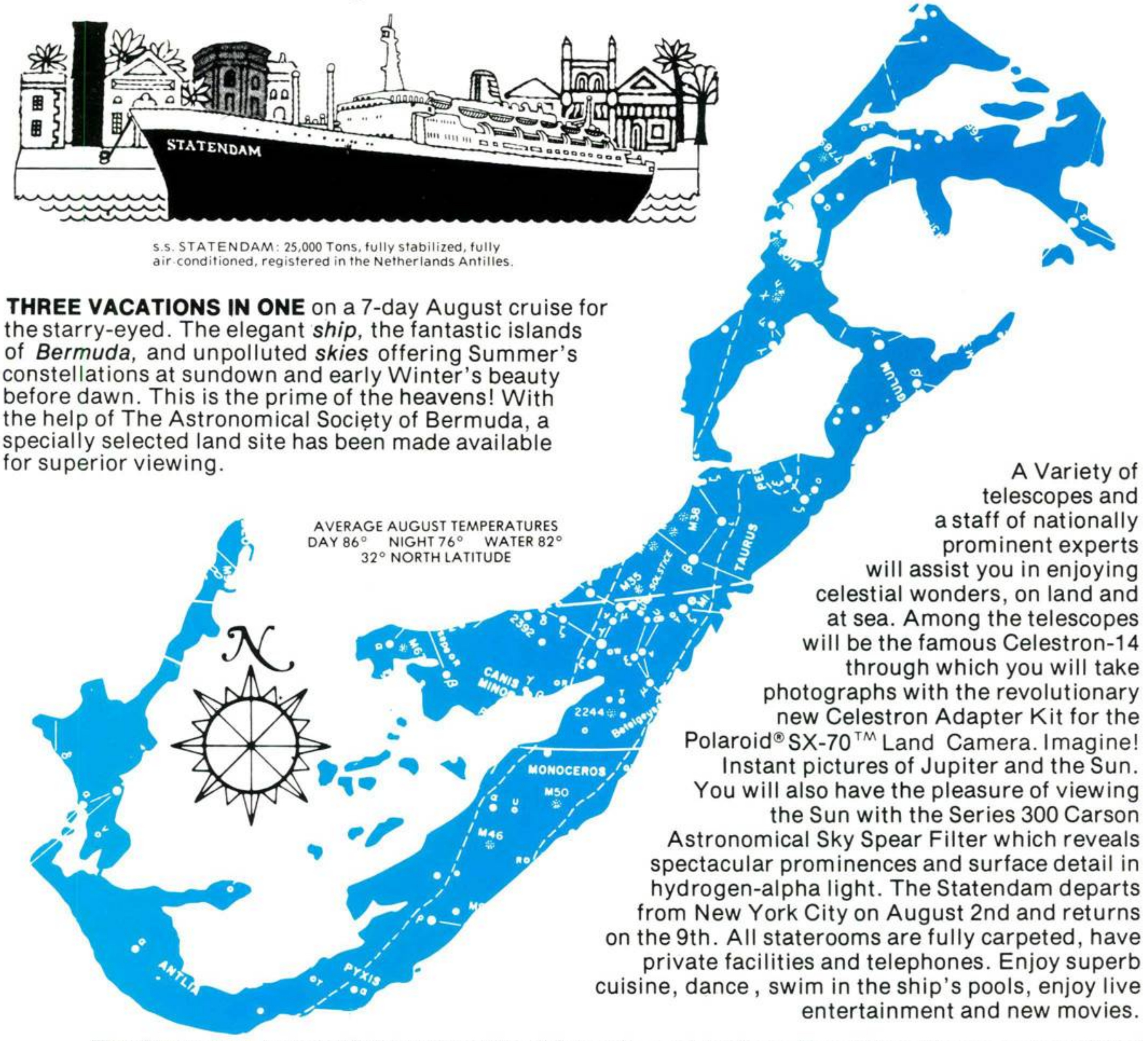

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Cover

Photograph by James K. Rouse

Immersed in Earth's shadow, the moon shines with a dull coppery glow less than 1/100 its normal brightness. Sunlight that has been heavily refracted and filtered through our planet's atmosphere is responsible for preventing the shadow from being inky black. This lunar eclipse, seen over North America on Feb. 9-10, 1971, was similar in general characteristics to this month's eclipse. Gazer's Gazette has full details beginning on page 50. An eight inch f/7 Newtonian reflector was used at prime focus for this eight second exposure on High Speed Ektachrome, processed to ASA 400.

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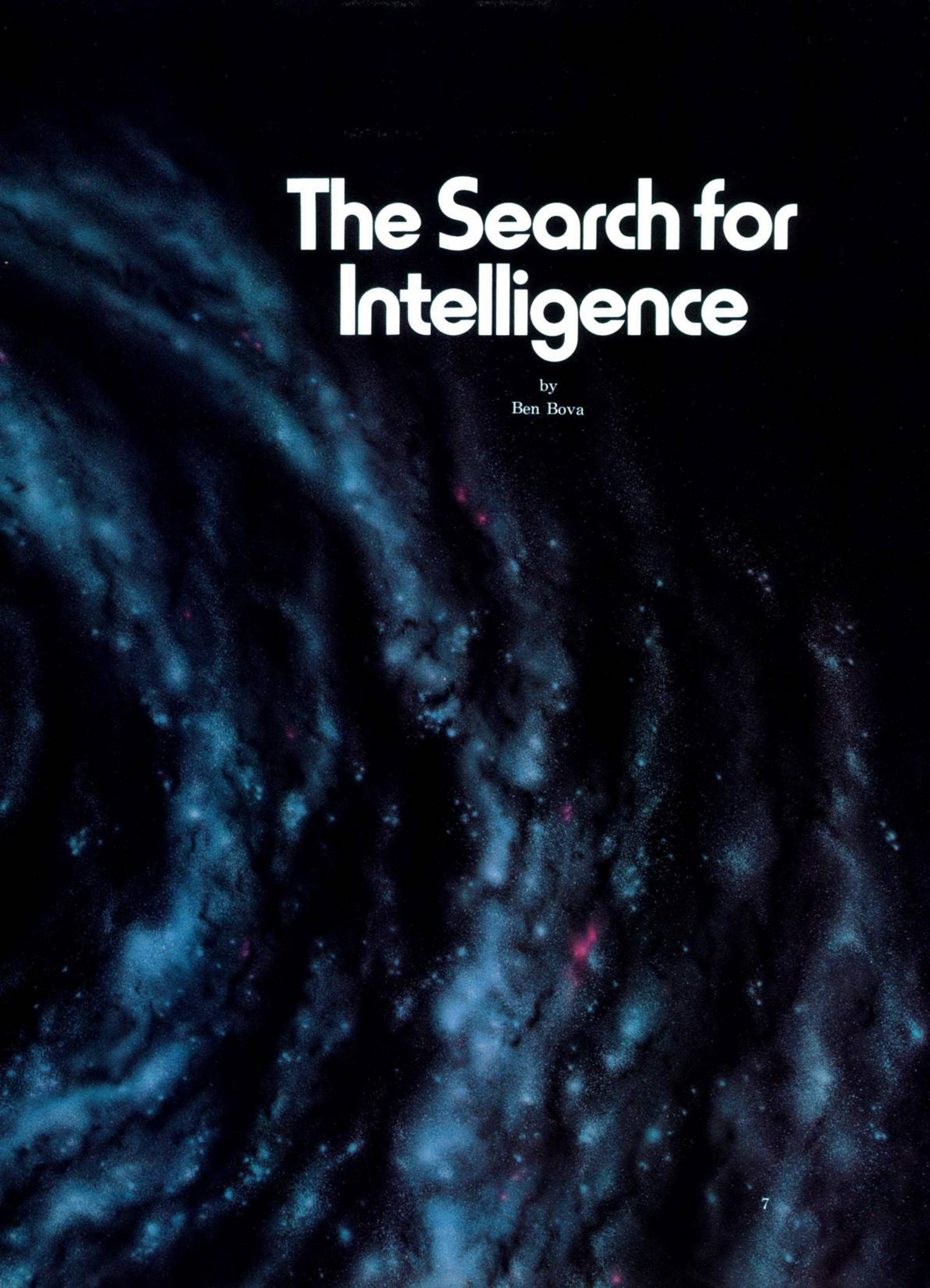


The Search for Intelligence

by
Ben Bova

Since the deluge of "flying saucer" reports shortly after World War II, skeptics have been demanding some solid form of evidence to substantiate the claims made that unidentified flying objects are actually spacecraft from other worlds piloted here by intelligent extraterrestrial astronauts.

Eyewitness reports of UFOs have always been held suspect, because investigations have shown them to be often unreliable and always unverifiable. A person says he saw a flying saucer. Fine! But there's no firm evidence, nothing to back up the claim. Science lives by what it can measure; everything else is just talk.

In the December 1974 issue of this magazine, the article entitled "The Zeta Reticuli Incident" went beyond mere talk. It presented what might well be the first substantial evidence of extraterrestrial visitation.

Caption for page 6

Like a swarm of some monstrous celestial insects, the great Hercules cluster (M-13) hovers 15,000 light-years above the main deck of stars that forms the spiral arms of the Milky Way galaxy. This globular cluster of some hundreds of thousands of stars was the target of the first message beamed from Earth — our first intentional radio "hello" to distant civilizations. The sun is invisible from this distant viewpoint, buried in the mass of stars at the right. Globular clusters like M-13 consist of stars billions of years older than the sun. Such stars seem less likely to have inhabited planets than those in the spiral arms of galaxies. This article explores how we might go about detecting other intelligences beyond Earth.

Artwork by Victor Costanzo

This new evidence is not conclusive. But it *is* strong enough to suggest what the next step should be in our search for extraterrestrial intelligent life. We — meaning the entire human race — should be focusing significant effort to determine if an intelligent civilization lives near the star Zeta Reticuli, or any of its celestial neighbors.

We have the technology to make such a search for signs of intelligence. Possibly our technology is now advanced enough to achieve success, and make an unmistakable contact with an intelligent extraterrestrial race. This article will show some of the problems and the chances for success.

First, though, we should briefly recapitulate the evidence that has stirred this hope.

As explained in detail in the December 1974 article by ASTRONOMY editor Terence Dickinson, the evidence consists of a map drawn by Betty Hill, who was allegedly taken aboard a UFO in 1961 with her husband. Inside the craft, she saw a three-dimensional star map which she reproduced in 1964 under posthypnotic suggestion. In 1969, Marjorie Fish (an Ohio schoolteacher and amateur astronomer)

Stars With Dark Companions

Star	Distance (light-years)	Mass of Star (sun=1)	Mass of Companion (Jupiter=1)	Comments
Proxima Centauri	4.3	0.15	1.8	observations need confirmation
Barnard's star	5.9	0.15	1.1 and 0.8	other calculations suggest three or more planets
Lalande 21185	8.1	0.35	10	good data
Epsilon Eridani	10.7	0.6	6	good data
61 Cygni A	11.2	0.6	8	good data
BD+5°1668	12.2	0.3	10	more observations needed
Kruger 60A	12.8	0.3	10	more observations needed
AOe 17415-6	15.7	0.3	10	more observations needed
BD+20°2465	16.1	0.2	10	more observations needed
70 Ophiuchi A	16.7	0.9	12 and 10	more observations needed
BD+43°4305	16.9	0.2	10	more observations needed
Cin2347	27	0.3	20	more observations needed

discussed Mrs. Hill's rough sketch with her, and then set about constructing three-dimensional models of the stars in the sun's neighborhood, to see if she could find the same pattern of stars.

She did. Ms. Fish's model showed that the Hill map coincides closely with the positions of 16 solar type stars — including the sun — as seen from the point of view of the double star Zeta Reticuli.

The chances of this being a coincidence are considered astronomical (no pun intended). Ms. Fish had to spend more than five years working out models of the stars in our area of the Milky Way. She needed the latest and most accurate catalogs available to produce her three-dimensional map.

So where do we go from here?

To begin with, let us assume that the map *is* authentic, or at least an excellent spur to seek further verification of the existence of this interstellar civilization. How do we go about determining if any of these 16 stars — or any other solar type stars — actually harbor an intelligent civilization?

The first step might be to try to find out if any of these stars are accompanied by a planetary system. Mrs. Hill stated that the extraterrestrial visitors were quite human in form; we can assume, therefore, that if they exist at all, they must have originated on a planet rather like our own Earth.

Do any of these 16 stars possess planets?

The simple truth is that no astronomer has ever seen a planet orbiting another star — although most agree that billions of stars must have planets associated with them. The problem is distance: Even the closest stars are so far away that any planets they might possess would be too dim for us to see.

Imagine you're on a planet of Alpha Centauri (if one exists) and you're looking back toward the sun with the best astronomical equipment we now have on Earth. To make things easy for you, we won't even ask you to find Earth. Instead, try to find Jupiter which is much bigger and brighter.

Even with a 200 inch telescope such as the Hale reflector at Mt. Palomar, Jupiter would be invisible. It would be one billion times fainter than the sun, and its feeble light would be drowned out completely by the mighty glare of the nearby sun.

However if you watched the sun carefully for many years, you would notice a slight weaving as it moves through space. Instead of traveling along a straight line path, the sun is bobbing back and forth ever so slightly. You would conclude that something is pulling the sun back and forth — pulling with the force of gravity.

If your measurements were precise enough (more precise than we are capable of measuring with today's telescopes), you would find that the "something" is moving in an orbit around the sun every 12 years or so, and its mass is about 1/1000 that of the sun. You would finally conclude that the "something" is either a very small "dark" star or a rather large planet. You would, of course, have discovered Jupiter.

Astronomers on Earth have found planets around a few of the nearest stars in this indirect fashion. They call these unseen worlds *dark companions.*

Of the 59 stars within 17 light-years of the sun, at least four are known to have dark companions and there are numerous suspected companions. Twenty-nine of these nearest stars are double or triple, which makes the search for dark companions very tricky — unless the stars are separated by enough distance so that minute gravitational shifts caused by possible planets are not swamped in the gravitational effects caused by the companion stars.

Of the five closest stars, Alpha Centauri is a triple system, Barnard's star and Lalande 21185 have dark companions, Sirius is a double and Wolf 359 appears to be alone.

This *astrometric* technique for detecting dark companions is so delicate that it can be used only over very short distances, astronomically speaking. The star being observed must be of low mass so that the companion produces significant wobbling over years of observation. The most distant star for which such a measurement has been successfully carried out is the red dwarf BD+43°4305, which is 17 light-years from the sun — although there are some suspected cases as far out as 27 light-years. It seems likely that there are many more planets of other stars, and many smaller, Earthlike planets as well, that simply cannot be detected by present astrometric techniques.

Of all the solar type stars beyond our solar system, only Tau Ceti (nearly 12 light-years distant) is within the distance limit in which astrometric planet searches have a chance of working. Tau Ceti is a G type star like the sun, and as we shall see shortly, it has been the object of radio studies seeking evidence of intelligent life. But so far no astronomer has been able to detect a dark companion of Tau Ceti.

Direct visual discovery of planets around other stars seems unlikely, even when large optical telescopes are placed in orbit above Earth's murky atmosphere. And the astrometric technique for indirectly detecting planets is of limited applicability because the wobble of a star caused by Earth sized planets is so slight that even highy refined equipment will not be able to detect it. This is why astronomers have turned increasingly to radio telescopes over the past three decades in their searches for life in the universe.

In 1960, astronomers at the National Radio Astronomy Observatory in Green Bank, W. Va. searched for intelligent radio signals from two stars — Tau Ceti and Epsilon Eridani. The program, under the leadership of Frank Drake, was called Project Ozma (after the Queen of Oz, from the series of books by L. Frank Baum). Ozma was not a high powered program. The astronomers used an 85 foot diameter radio telescope — a moderately powerful instrument at that time. However, their observing time was limited to 200 hours, squeezed out of more than a year's duration.

No signals hinting at intelligent life were found emanating from either star. But on the other hand, if astronomers living on planets of Tau Ceti or Epsilon Eridani had been running their own version of Ozma at precisely the same time, they would have gotten precisely the same negative results from us. The only way Ozma could have succeeded would have been if someone at the target star had been deliberately beaming out a powerful signal. The equipment used for Ozma was not strong enough to pick up random radio broadcasts from civilizations a dozen light-years away.

In the 15 years since Ozma, several groups and individuals have searched for intelligent radio signals from space. For the most part, these studies have been very informal with time on various radio telescopes snatched here and there, when available. This is like trying to find a needle in a haystack — by looking only once in a while, and then only for a few moments at a time. You'd have to be incredibly lucky to find anything that way.

Ozma II has been running intermittently since December 1972, under the leadership of Benjamin M. Zuckerman of the University of Maryland and Patrick Palmer of the University of Chicago. Using the 300 foot antenna at Green Bank, they have logged some 400 hours of observation time in slightly more than two years.

One of the major problems facing radio astronomers who seek extraterrestrial intelligence is: What frequency should we be tuned to? The radio spectrum is enormous, and there are literally a billion possible frequencies for interstellar radio communication. The 21cm wavelength "song of hydrogen" (frequency 1420 MHz) is favored by many, because it is a natural signal emitted by the clouds of neutral hydrogen gas in interstellar space; therefore, radio astronomers would naturally tune to it in their investigations of the universe.

On the other hand, precisely because it is such a prevalent source of radio "noise", others have suggested different frequencies for purposeful communications, such as a whole multiple of the hydrogen "song" — 2840 or 4260 MHz.

And make no mistake about it: Radio signals are now, and will be for some time to come, the best way for us to make contact with extraterrestrial intelligences. The newly refurbished Arecibo radio telescope, for example, operating at a power of one megawatt, could detect signals from a similar transmitter over a range of 70,000 light-years. This means that the Arecibo "dish" could communicate with anyone in the galaxy who has similar equipment.

Why is radio better than other forms of communications, such as lasers? Basically, it is because there are *windows* in the sky.

The so-called vacuum of interstellar space is far from empty when it comes to sending messages through it. It is crackling with natural radio noises, such as the 20cm hydrogen emission. It is dotted with lanes of gaseous nebulae and dust clouds that block or scatter optical and infrared wavelengths — and these clouds lie exactly where we want to look most deeply (along the star-rich central plane of the galaxy). Radio waves can penetrate these clouds. There are windows in the spectrum of electromagnetic frequencies that allow radio waves to penetrate where shorter waves, such as visible light, are stopped.

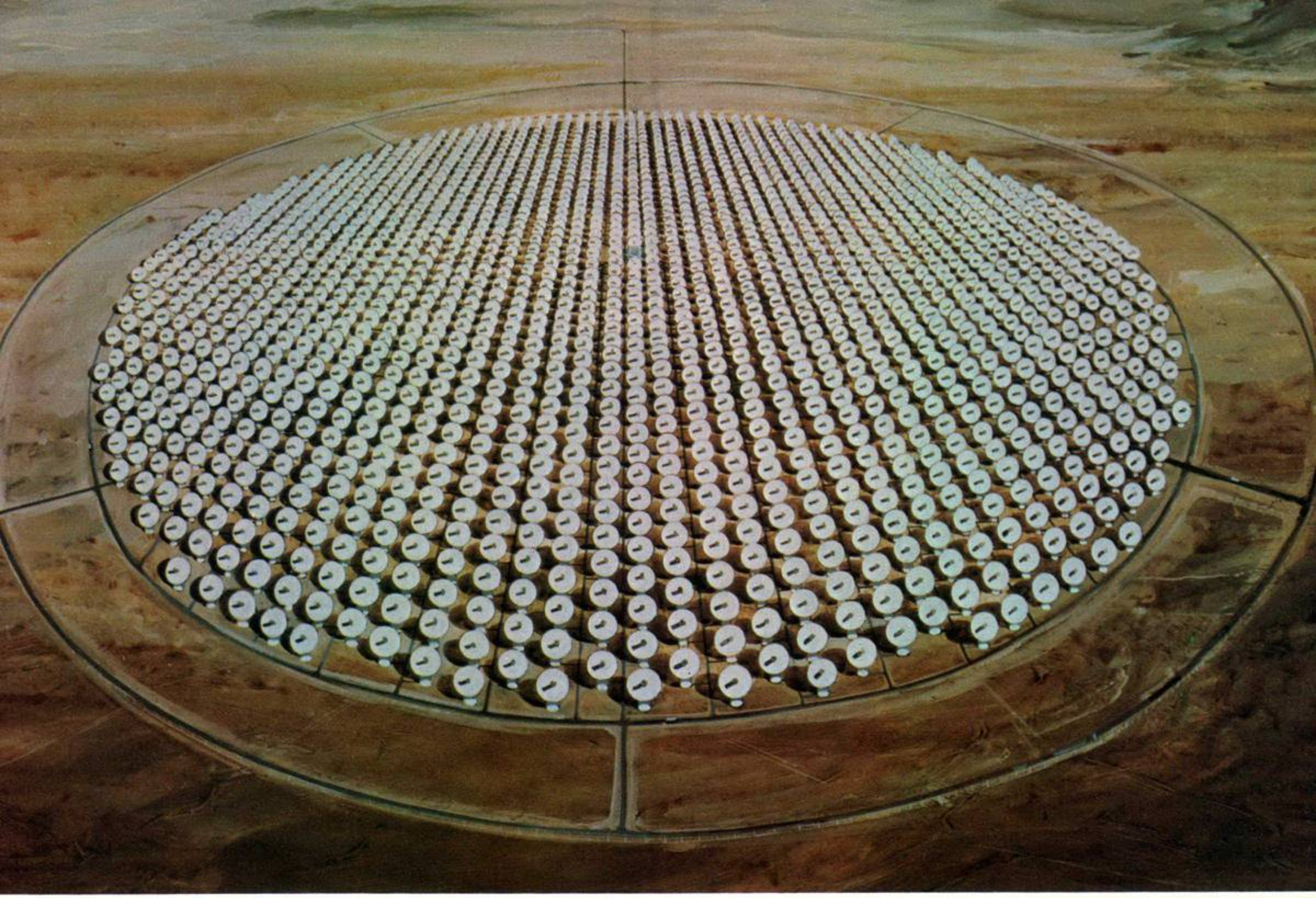
The fact that radio waves can get through these windows means that, for a given amount of energy input, radio waves can travel farther and reach more stars than optical or infrared waves sent out from a laser. A one megawatt laser transmitter, for example, would be thousands of times less effective for interstellar signaling than a similarly powered radio transmitter. This is why astronomers are depending on radio telescopes to contact other civilizations.

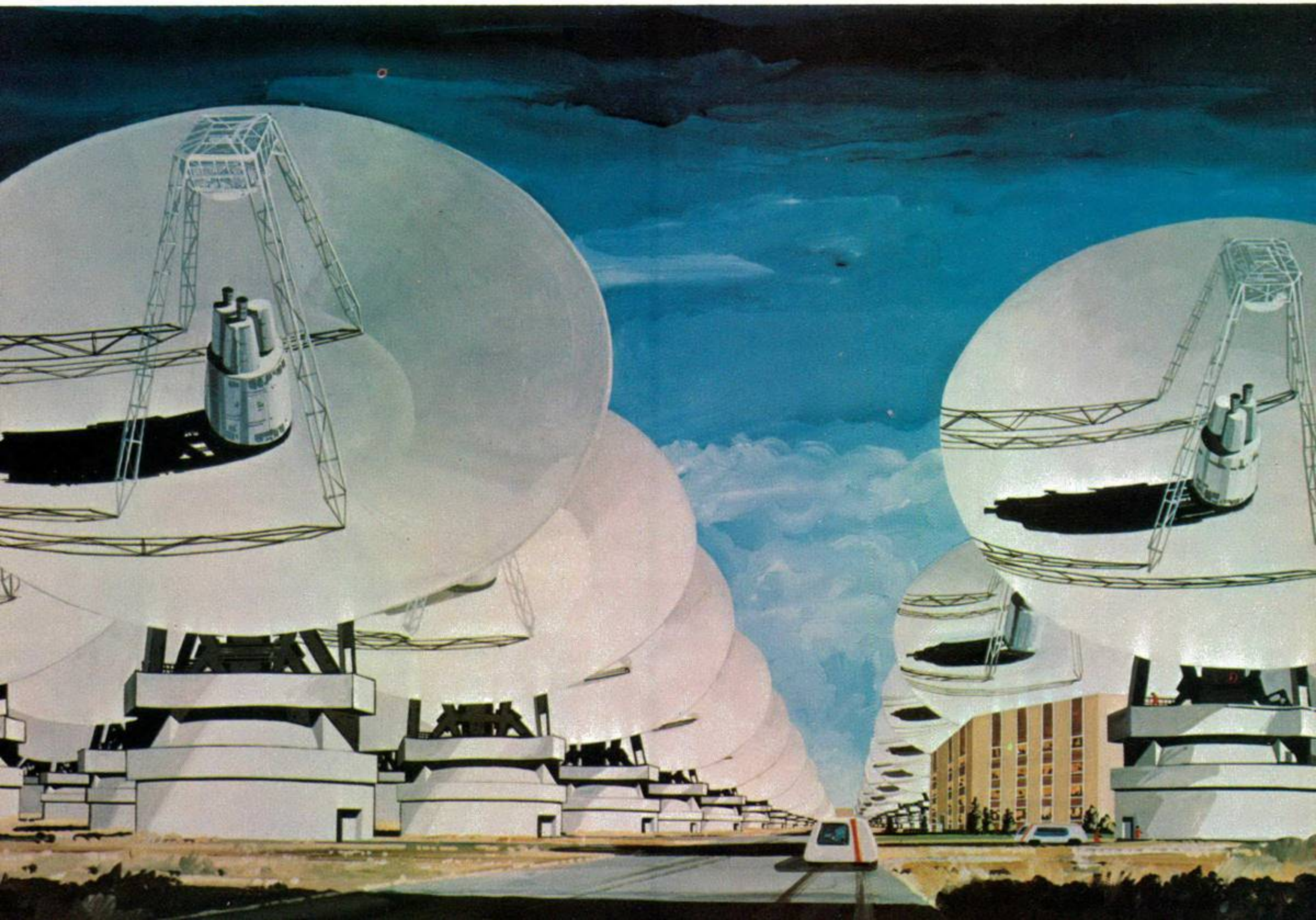
There are about a billion discreet frequencies in the radio portion of the electromagnetic spectrum that are available for interstellar communications. The limits to the usable frequencies are set, on the low frequency side, by the background radio noise of the galaxy itself; on the high frequency side, it's the basic quantum noise inherent in the receiving equipment that sets the limit. Still, this enormous spectrum of possible signal-carrying channels poses the toughest dilemma in the search for intelligent signals. It's an embarrassment of riches.

Of course, a highly advanced civilization may have much improved lasers or other communications technology that we are totally ignorant of. If so, they may be signaling to us madly — but we have utterly no way of knowing it. But we do know radio, and it is a powerful enough tool to reach millions of stars. We may be safe in assuming that an extraterrestrial race will also use radio in an attempt to contact its "primitive" interstellar neighbors.

In size and complexity, the proposed Project Cyclops radio antenna array completely dwarfs any research instrument yet built by man. From the air it would appear as a 10 mile diameter glistening forest of 1,000 to 2,500 dish antennas. A maze of roadways and underground tunnels would interconnect this complex to a central control building. Here, a computer would electronically combine signals from the 330 foot diameter antennas so that they function together as one giant three mile diameter radio "eye". This titanic project would require 20 to 30 years of construction and cost $10 to $20 billion, at the average rate of about $600 million per year. As mankind's most powerful observatory, Cyclops could provide a detailed map of Venus' surface, study the corona of a nearby star, and communicate with interstellar space probes. Most importantly, Cyclops would conduct a continuous systematic search for extraterrestrial civilizations by *eavesdropping* on their daily communications activity or seeking beacons that may exist for the specific purpose of signaling other intelligences.

NASA Artwork





In 1970, NASA and the American Society for Engineering Education co-sponsored a study of the technical problems of interstellar communications. It was called Project Cyclops, and one of the engineers' goals was to come up with recommendations on how we could realistically search the skies for intelligent signals.

The Cyclops researchers worked out at a technique — on paper — by which radio astronomers could scan an individual star through the entire radio frequency spectrum in approximately 1,000 seconds (about 17 minutes). This is an important step forward, because earlier thinking had shown it would take 10 billion seconds, or 300 *years*, for an effective search through all the possible radio frequencies for a single star.

The Cyclops report showed that a thorough study of all the solar type stars out to about 1,000 light-years — a total of roughly a million stars — could be done in about 30 years. This is a long time, but still many times better than the previous techniques offered. And this is a *thorough* study — a systematic sweep through all the radio frequencies for each star, to search for any possible hint of deliberate signaling.

Unfortunately, such a program would take not only a lot of time, but huge amounts of money. Cyclops would require an array of radio telescopes with an effective aperture (lens diameter) of three miles. Building the radio telescope facility would cost more than $10 billion. While this is about 1/2 the cost of the Apollo lunar landing program, it seems unlikely that any foreseeable American president or Congress will appropriate that much money for research leading to a possible contact with extraterrestrial intelligence. (Not unless someone convinces them of a danger of invasion from space!)

Getting back to the 16 solar type stars in the Hill map, where do we stand in our thinking about searching them and other similar stars for signs of intelligence?

We cannot determine if these stars have planets orbiting about them. The astrometric technique is not powerful enough to reach that far. This situation might improve when we place very large telescopes in orbit, but that won't happen for at least another decade.

Looking for signals from lasers, or in the infrared or ultraviolet portions of the spectrum, or from other unlikely sources (gravitational waves?) would probably be fruitless. These techniques simply do not carry the same information value that radio communications do.

Using the most advanced radio techniques, it might be possible to scan each of the target stars through the entire radio spectrum, seeking the frequencies that they are using for communications, in something on the order of less than an hour per star — if we had the Cyclops type of facility. Without it, each of the solar type stars can still be scanned carefully, but it will take much longer to do the job — many years per star.

Moreover, the civilizations that may exist among those stars might not be sending purposeful messages toward us. Why should they? If they are actually responsible for all the UFO sightings over the past 30 years, they certainly *are not* trying to make formal public appearances among us. They may be studying us the same way anthropologists study chimpanzees in the wild — by blending into the background and becoming invisible.

Of course, we could send out a signal that tells them we're alive and seeking pen pals. This is exactly what the astronomers at Arecibo did on Nov. 16, 1974.

The occasion was the reopening of the world's largest radio telescope after its 1,000 foot dish had been resurfaced — a project that took more than a year. Using a binary-coded "picturegram" technique worked out by Frank Drake of the National Astronomy and Ionosphere Center of Cornell University, the astronomers aimed a complex "Hello!" at the globular star cluster M-13 in Hercules. M-13 contains more than 300,000 stars, and is some 24,000 light-years from us (see Astro-News, February 1975).

Cornell astronomer Carl Sagan estimated there could be one chance in two of an intelligent civilization in M-13. And the width of the radio telescope's beam will just fill the cluster's diameter after its 24,000 year journey. The message was sent at a wavelength of 12.6cm (2380 MHz) — a region of the radio spectrum where natural noise interference is comparatively low, and thus a relatively weak signal can be transmitted for long distances. The Arecibo signal was powered by a 450 kilowatt transmitter, far from the loudest shout that modern technology can deliver for us.

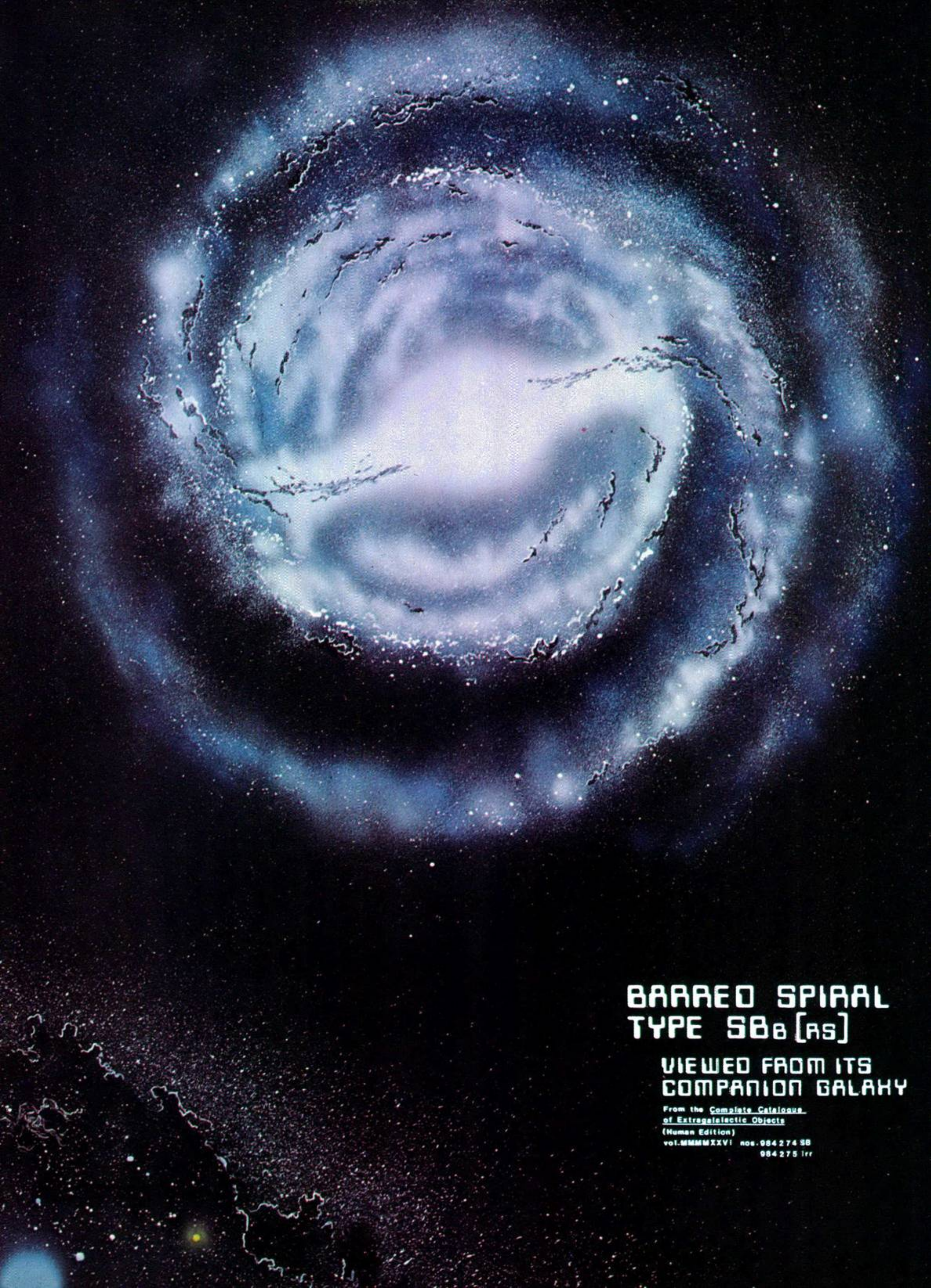
What more can we do?

We can play a game that science fiction writers have invented, and social scientists such as "futurologists" have learned to borrow for their own work. It's called "What if?" Many intriguing science fiction stories have been constructed by a writer asking himself, "What if a terrorist organization put a nuclear bomb in orbit?" Or, "What if a computer became truly self aware and intelligent?"

In our case, we can ask: "What if there really are advanced civilizations among those 16 stars on the Hill map, and they have sent occasional scouts to visit our planet? What clues does this give us in

What would a message from an advanced civilization consist of besides "hello"? Some scientists suggest that the transmission would first mathematically describe how to decode the rest of the greeting. Interspersed between these school lessons would be volumes of information and perhaps even images about the nature of the message's senders, their world, and location in the galaxy. Several advanced societies might establish a galactic civilization, pooling their knowledge and discoveries and sharing this information with backward newcomers like Earth as depicted in the illustration on the right.

Artwork by Jon Lomberg



BARRED SPIRAL
TYPE SBb [rs]

VIEWED FROM ITS
COMPANION GALAXY

From the Complete Catalogue
of Extragalalactic Objects
(Human Edition)
vol.MMMMXXVI nos.984274 SB
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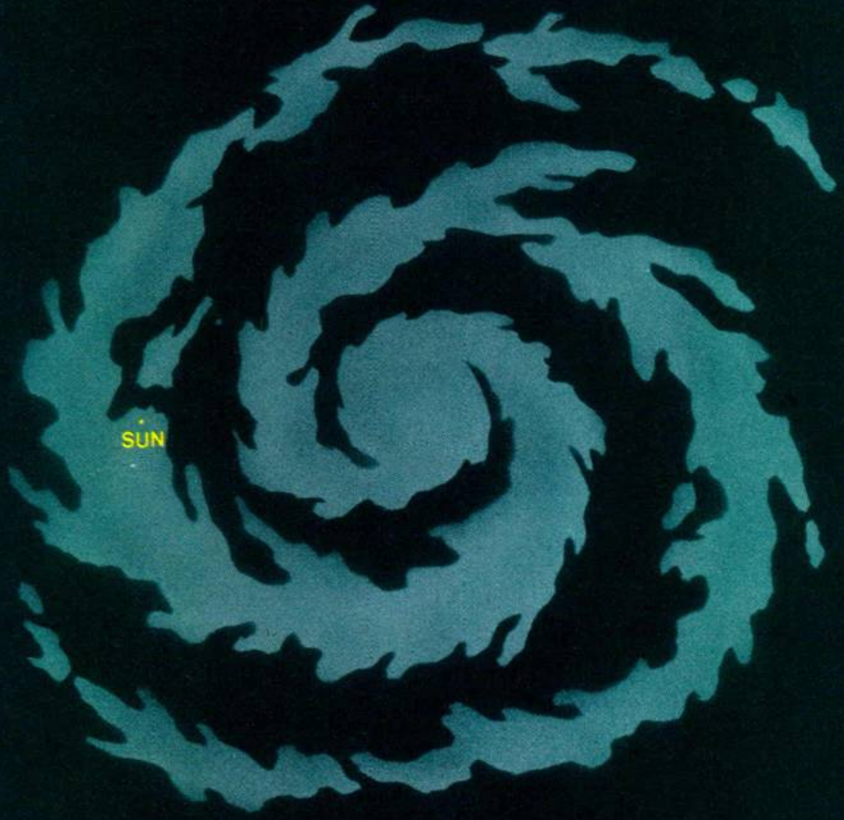
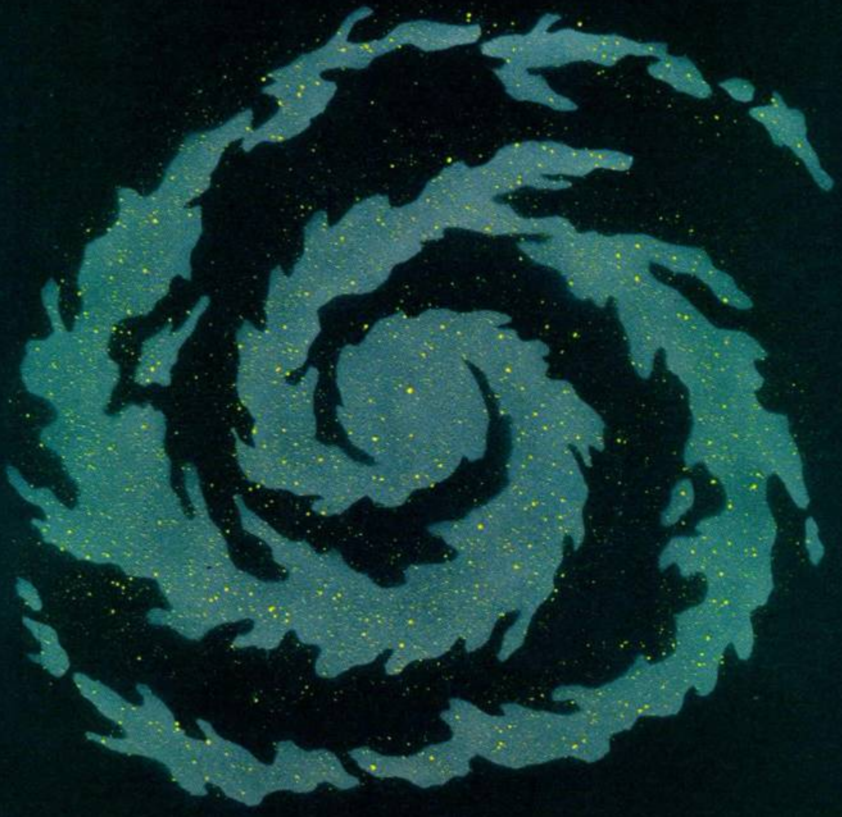
Are We Alone in the Galaxy?





our search for a means to communicate with them?"

Remember, what we are seeking primarily is a clue as to which communications frequencies they use. Once we have a good idea of which frequencies to tune to, we should be able to contact them — or at least eavesdrop on their communications.

All right, let's turn the problem around. *We* are now the citizens of an advanced interstellar society. We are scouts, seeking out other intelligent species among the yellowish stars in our area of the great Milky Way galaxy. What would attract us to Earth?

To begin with, we would seek stars of the G class, or late F and early K types. As discussed in the December 1974 article, these are the most likely harbors for our kind of life. But there are literally a million of them within 1,000 light-years of home; they can't all have native life forms, and we don't have the time, energy, or inclination to visit each one of them individually. How do we pick out the most likely prospects?

We listen. We use radio telescopes — possibly our scout ship is itself a gigantic radio antenna — and we try to pick up the natives' primitive radio communications.

In 1901, Guglielmo Marconi transmitted the first wireless radio signal across the Atlantic Ocean, and radio communications began on this planet. While this communication depended on the ionosphere's reflection of the radio waves, some of the radio energy leaked through the ionosphere and escaped into space.

At this moment there is a huge ephemeral bubble of electromagnetic energy expanding through space at the speed of light, 74 light-years in radius and centered on Earth. Perhaps our first radio signals are now so weak, 74 light-years out in space, that they can no longer be detected against the cosmic radio background noise.

But an interstellar scout ship with the proper equipment would see Earth today as a powerful source of radio emission, mostly centered around the frequencies used by commercial television and FM broadcasters — from about 50 to 1,000 MHz. In those frequencies (which pass freely through the ionosphere), Earth outshines the sun. This is a certain clue to the existence of life on our planet.

We can attempt the same technique in seeking evidence of life on the 16 stars of the Hill map. Make the assumption that the aliens are very much like us — that their earliest electronic communications used pretty much the same frequencies that ours did. Scan those frequencies, seeking evidence of their local radio, telephone, and television broadcasts — and perhaps the communications links between their home worlds and their interstellar ships.

Eavesdropping on planetary chatter is much more difficult than receiving purposeful signals beamed toward us. It will take much more power from our receiving equipment to overhear the Zeta Reticulans' version of "Hello Mom, happy birthday". But the Arecibo radio telescope could be upgraded to attempt the task.

The advantage of this approach, of course, is that we eliminate all but a few of those possible billion communications frequencies, and concentrate on the few that we suspect the aliens are really using. We have swept most of the straw away from the haystack.

This approach may be entirely wrong, and we could miss the aliens' conversational chatter simply because they have chosen a completely different set of frequencies. But at least it is a beginning that is based on more than a blind stab at the radio spectrum.

However, if the aliens are advanced enough to send scouts to our planet, then their era of idle radio and TV chitchat may be centuries or millennia behind them. Assuming the aliens are beyond our level of technological and social development, what should we look for?

To begin with, we should certainly be seeking "first contact" messages such as the one Drake and his Arecibo colleagues sent last November. The trouble with that "Hello!" is that it was sent on only one day. From all we have learned, it seems certain that such messages must be beamed out for years — perhaps centuries — if we expect them to be picked up by the scattered civilizations out there.

As we've seen, sporadic and haphazard attempts such as Project Ozma to find such signals have brought no success. Such listening — and sending — projects must be done continuously for many generations if they are to succeed. Even if the multitelescope array suggested by the Cyclops group was to be built, contacting advanced civilizations would still take time — and lots of it.

What other detectable clues would a highly advanced civilization produce?

A very advanced civilization would be able to produce and harness much more energy than we can. It would have left behind such wasteful and stopgap energy sources as fossil fuels long ago, and would be utilizing either solar energy or thermonuclear fusion.

If the aliens are using fusion power, they are generating large amounts of waste heat on their

The number of civilizations in the Milky Way galaxy that are technologically equal or superior to us is unknown. Estimates range from one civilization — us — to more than a million advanced cultures. These two extremes are illustrated here with each dot representing one civilization. The deciding factor in such estimates is the figure used for the length of time a civilization is capable of communicating with (or receiving communication from) another advanced culture. In our case, this figure is 15 years. If civilizations annihilate themselves within the first few hundred years of their existence in the communicative era, then the lonely estimate is correct. If, on the other hand, advanced races learn to live with themselves and each other, the average longevity goes up enormously and the galaxy is teeming with sophisticated life forms.

Artwork by Victor Costanzo

planet which might be visible to us in the form of infrared radiation. Several astronomers have pointed out, however, that an industrialized civilization would have to produce enough heat from its factories and cities to melt the planet before we could detect any significant infrared radiation (IR) with our IR telescopes here on Earth.

Really?

Certainly the natural infrared radiation from a G type star would drown out any additional infrared being pumped out by a highly industrialized, energy-rich planetary civilization. It's difficult to see, for example, how our own civilization could produce even half a percent of the heat we receive daily from the sun without stirring up cataclysmic changes in Earth's climate. So most astronomers feel safe in assuming that searching for stars with an excess of infrared emission in their spectra is not a fruitful way to detect planets with civilizations.

But his is assuming that a highly advanced civilization with energy to burn (literally) will always stay confined to the surface of its home planet. Patently ridiculous. Precisely *because* factories produce waste heat and other forms of pollution (and need constant supplies of resources), an advanced civilization will move its industrial centers off-planet. Even in our own primitive stage of development, we have started experiments on Skylab to investigate the possibilities of conducting manufacturing operations in orbit.

Smart aliens will move their industries into orbit around their home planet, so that their lands can be green and clean of industrial pollution (assuming, always, that the aliens live under a G type star and are enough like us to depend on water and chlorophyl).

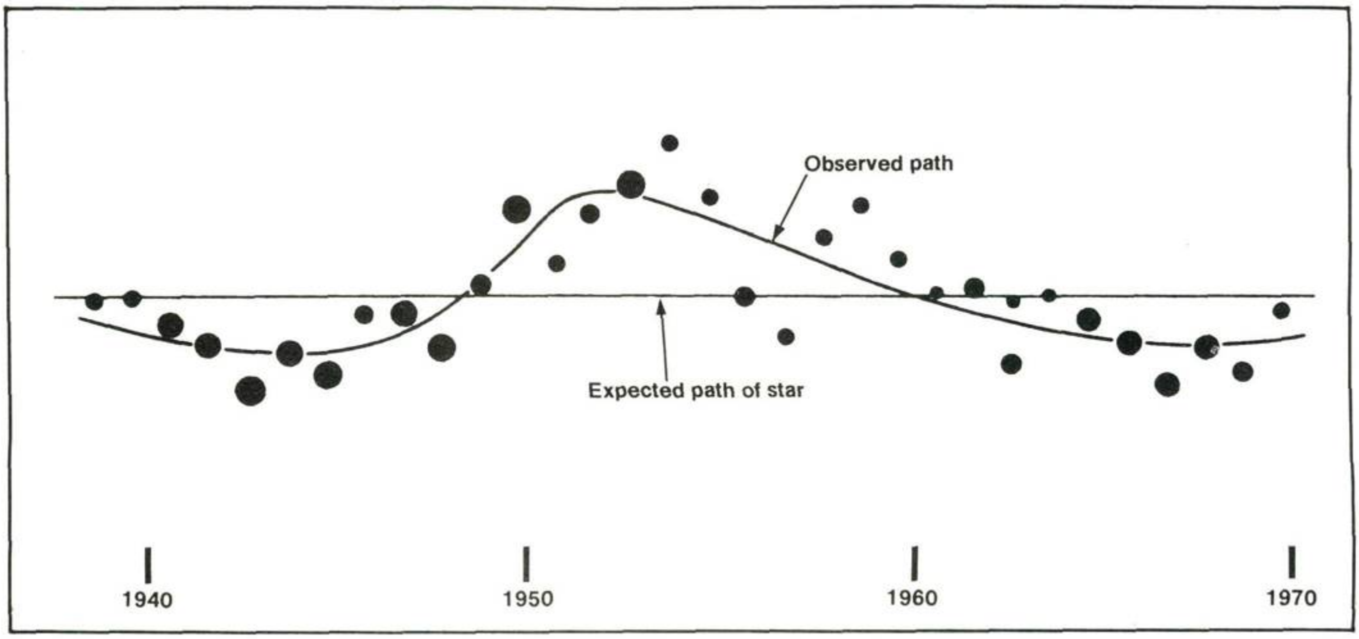
They will also begin to draw their natural resources from the uninhabited planets of their solar system, because this too will help to keep their home world's ecology from being gutted and destroyed.

Eventually they will spread their industries, commerce, colonies and cities across their planetary system. And they will inadvertently and inevitably be radiating infrared heat emissions as they expand their civilization. So perhaps the search for infrared-rich stars would not be such a waste of time after all. We may not be able to detect the planets *per se.* But a highly industrialized interplanetary society will leave an infrared "signature" that we may be able to detect — either from Earth's surface or from orbit with IR telescopes.

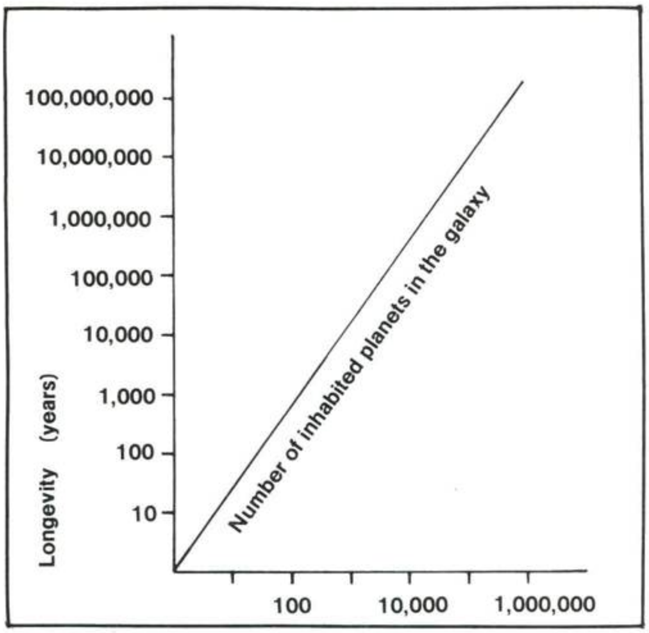
What's the next step?

Freeman Dyson of Princeton University pointed out many years ago that as a civilization advances in technological prowess, it will begin to utilize the energy of its parent star more efficiently. Dyson foresaw that a really far advanced civilization could build a spherical shell around its star, to capture all the energy that the star radiates. They would utilize the materials of the planets in their system and construct their shell at the same radius as their home planet's orbit. Instead of being restricted to one planet's surface, or the surfaces of a few planets, they would have the entire inner surface of this titanic shell to live and work on.

What would such a supercivilization look like to us? All the energy radiated by the star at the center of the Dyson sphere would be trapped and



The wobbling motion of Barnard's star has been attributed to the gravitational influence of its planets. When both planets are lined up on the same side, the star is offset from the center of gravity of the system. This offset, although very small, has been observed for decades as explained in this article. (Dots are observed positions of the star.)



Many factors affecting estimates of the number of inhabited planets beyond Earth are in the realm of educated guesses. But one — the longevity of civilizations — is totally unknown; no particular estimate can be given much weight over another. As shown here, the length of time a civilization is capable of interstellar communication (its longevity) vastly affects the number of our potential cosmic relatives. Do advanced cultures learn to live with themselves? Today the answer is: no data.

utilized by the inhabitants of the shell. But they'd still have to get rid of their waste heat because no organism or machine is 100 percent efficient. The laws of thermodynamics hold even for very advanced civilizations, and the aliens would have to radiate their waste heat away from the outer surface of their shell. Most likely, the exterior of the shell would acquire a steady state temperature somewhere around what we call comfortable room temperature. The shell would thus be radiating in the infrared, at a wavelength of about 10 microns.

We would observe (if such a civilization existed) a sphere of about the diameter of Earth's orbit, radiating at a cool 10 microns or thereabouts.

In the infrared sky surveys made so far, many such IR sources have been discovered. Astronomers believe them to be protostars or dust clouds, rather than very advanced Dyson sphere civilizations. But astronomers are naturally cautious about interpreting such evidence; if there's a natural explanation for the observation, they will prefer it over an explanation that requires intelligence or life.

If some of what we have presented here sounds like pure fantasy, it's not. Almost everything discussed in this article can be found among the topics studied during the 1971 Conference on Communication with Extraterrestrial Intelligence which convened in the Soviet Union under the auspices of the Soviet Academy of Sciences and the U.S. National Academy of Science.

What then should be our plan of action in the search for intelligence beyond Earth? Several steps seem clear:

1) We should scan all nearby solar type stars in various regions of the radio spectrum in an attempt to detect any "leakage" of signals of the type that we ourselves use for planet-wide communication and broadcasting.

2) We should be beaming out "first contact" types of messages (such as was transmitted from Arecibo last November) on a continuous, purposeful basis.

3) We should be listening for such messages, too. While the $10 billion price tag on Project Cyclops gives most political decision makers the shudders, it might provide a useful source of employment in a sagging economy. Realize that NASA's space program was greatly accelerated under the Kennedy administration partly to bolster the economic slump of the late 1950s.

4) Advanced civilizations may expand into their planetary systems and produce significant infrared "signatures". We should be meticulously checking (and searching for) all sources of excessive infrared radiation.

5) If some of the infrared stars already identified are actually Dyson sphere civilizations, then enormously advanced societies exist in our galaxy. There is really very little we can do about them, except to send out "first contact" messages to let them know we exist. They are so far advanced beyond us that they might not care to contact us, or might have already found us and are either studying us covertly or subtly shaping us for purposes of their own.

Of course, there's the old science fiction idea that — since we don't know the intentions of our interstellar neighbors — we shouldn't let them know we exist. Or at least, we shouldn't reveal the location of our home world, since they might be dangerous and we wouldn't want them to visit and/or invade us. It's too late for that. We've already shouted "Hello" from Arecibo and sent a plaque on Pioneer 10 coasting out of the solar system. No one seriously expects repercussions from either event, but it is possible that these messages might be intercepted and backtracked to their source.

But long before that, we started beaming out radio and television broadcasts that are now wafting through space, showing and telling what we are like — or at least what the radio and TV networks show us to be like.

And that might explain, better than anything else, why no truly intelligent race has cared to make contact with us!

Ben Bova is editor of **Analog Science Fiction/Science Fact.** *He is author of numerous science and science fiction books, and contributed a major article to ASTRONOMY on extraterrestrial life for the August 1974 issue.*

COUNTDOWN TO 2001

by
James E. Oberg

Visions of permanent manned space stations and moon shuttle fleets may seem like comic book fantasies considering the multimillion dollar price tag of orbiting just one modest satellite. Today the cost of placing objects into orbit is about $1,600 per pound of payload.

Space travel does not have to be so incredibly expensive. It cannot be if man hopes to make space exploration — and exploitation — a growing, long-term enterprise. Today's discouraging price tag only reflects the embarrassingly awkward and extravagant way we have been taking our first baby steps beyond Earth. The space race mentality of the 1960s encouraged the development of giant size boosters that, after each flight, were leisurely dumped into the ocean like empty beer cans. If a similar approach was applied to air travel, each airliner would be discarded after a single flight — and passenger tickets would have to cover the full cost of a jet's construction.

The space program of the 1980s and beyond must drastically cut costs by building reusable space transports. Plans are already underway. NASA is presently developing the Space Shuttle, a hybrid airplane/spacecraft that will be capable of flying dozens of orbital missions. The Shuttle could shrink the current $1,600 per pound price tag to $160 per pound.

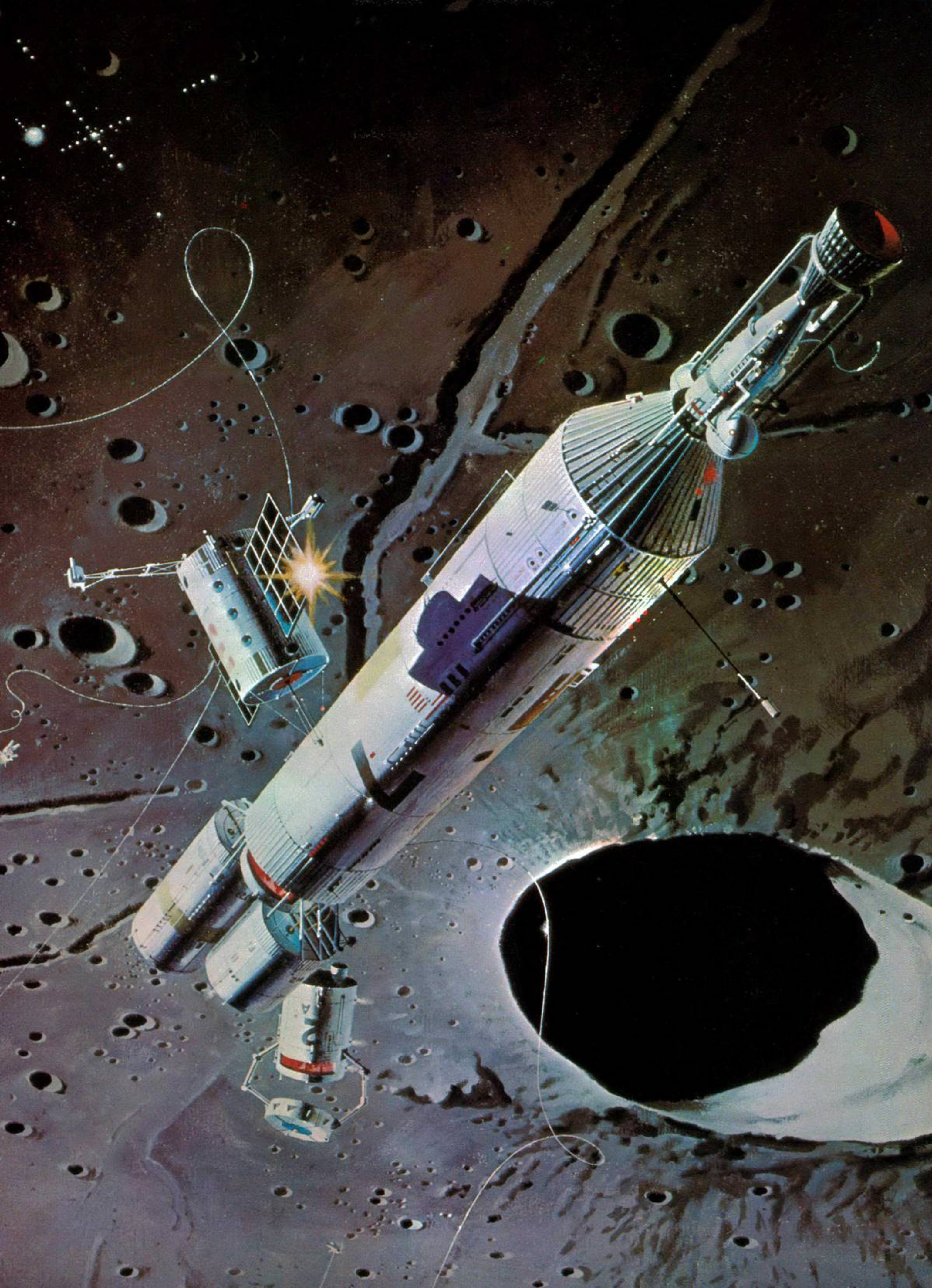
The Space Shuttle calls for the construction of a reusable "Orbiter" aerospace plane having an expendable fuel tank and two reusable solid-fuel boosters. At launch, the Orbiter's three engines burn fuel from the large tank attached to its belly, while the solid fuel boosters strapped to the tank also fire. Halfway into orbit, the two boosters fall away and parachute into the ocean — to be retrieved, refurbished, and used again. The Orbiter continues into space where it drops off the now empty fuel tank.

Comprising most of the Orbiter is the payload bay, a 60 foot long and 15 foot diameter section carrying the cargo of each particular mission. This could be a large satellite, a cluster of satellites, or a small deep space probe coupled to an extra rocket stage for sending the probe beyond Earth orbit. The Orbiter payload might also be a "Spacelab" manned module which remains attached to the launch vehicle for several weeks of space research.

At completion of the mission (which might have included retrieval of other satellites), the Orbiter heads back toward Earth. Once through the flames of re-entry (the underside of the fuselage and wings are coated with a special insulating heat shield), the winged Orbiter glides back to its launch base and lands like an airplane, to be refueled and used again.

This workhorse of the 1980s will be only the first of a family of reusable space transports. More advanced designs of the 1990s will further reduce space operation costs. The booster stage might be a manned vehicle that glides back to a landing strip after carrying the Orbiter part way to space, or the Orbiter might be modified to do it all alone as a "single-stage-to-orbit" vehicle. New dual-feed rocket engines which burn different types of fuel during different phases of the ascent will be the required source of power. Extra fuel tanks will take up most of the payload bay's volume, but the expendable

A rendezvous in lunar orbit resupplies a turn of the century moon base — the glowing cross of lights at upper left. At the far end of a nuclear ferry used to shuttle men and supplies from Earth orbit to lunar orbit, a stumpy "space tug" grasps cargo containers in its mechanical arms. The tug stacks the canisters on its top, and then descends to the base to unload and return. Sunlight glints on a solar panel of a space station as astronauts tethered to it maneuver by individual rocket packs. All three craft are in synchronous orbit above the moon base during the resupply operation. Artwork by Robert McCall



exterior fuel tank and the two solid-fuel boosters now under development would not be needed in this 1990s version. The modified vehicle could carry a few tons of payload into orbit and it would be completely reusable.

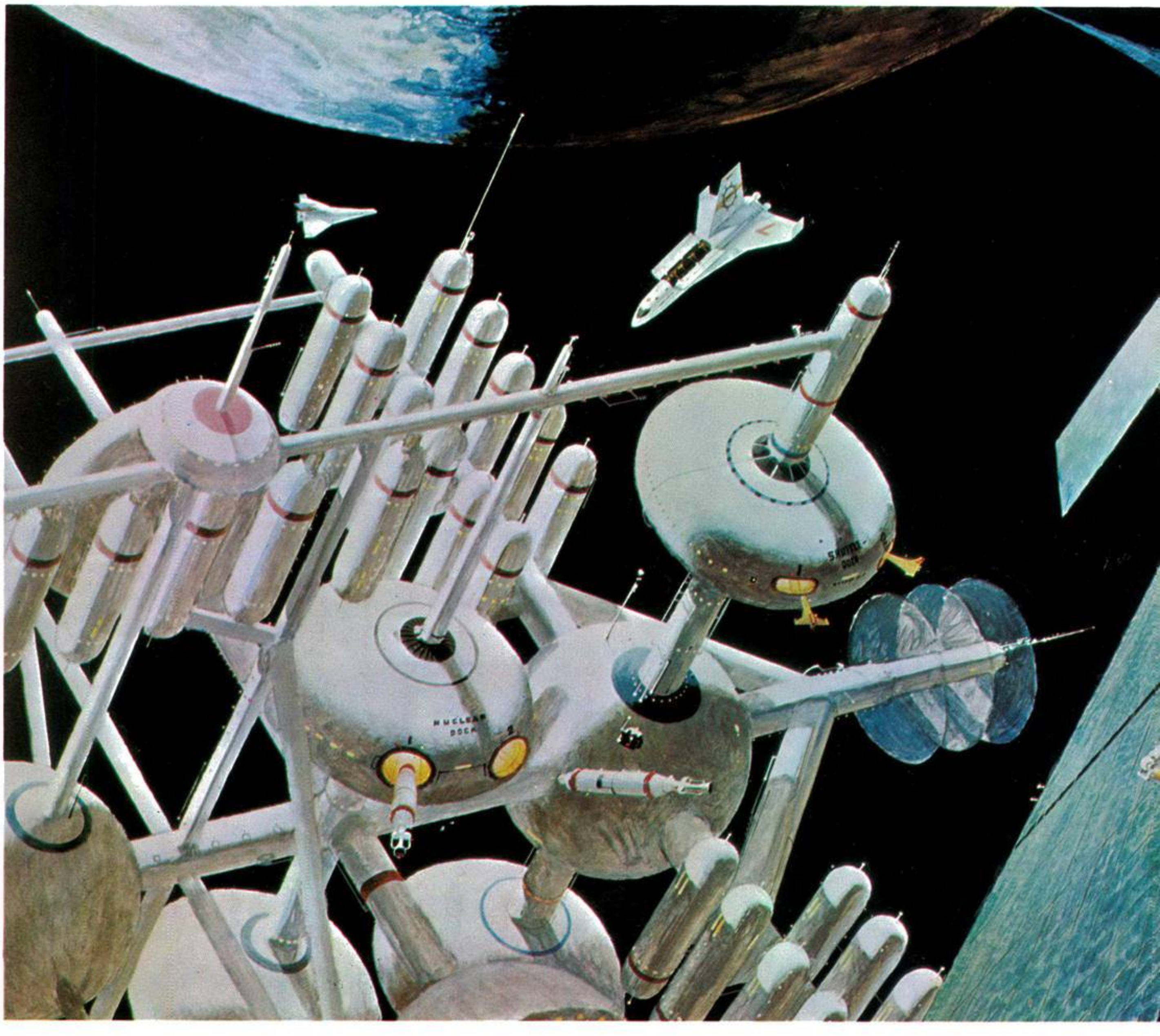
Follow-on space shuttles can be of various designs, each built for specific classes of missions. They will probably use dual-feed rocket engines as well as advanced metallurgical development resulting in stronger — yet lighter — airframes, rocket chambers and heat shields.

These and other vehicles will support the growing traffic between Earth and space at the turn of the century. In the 1960s, there were perhaps five manned space flights every year. NASA plans 50 manned flights per year in the 1980s; by the turn of the century, 500 manned spaceships may blast off annually. They will be aimed at Earth orbit, toward the moon and planets, and perhaps beyond.

Space stations of the 1970s orbit between 120 and 280 miles, and this narrow range of altitudes will still be used for the forseeable future. At altitudes below 100 miles, the slight air resistance is still sufficient to drag a satellite out of orbit within a few hours. Above several hundred miles, the spacecraft would penetrate the Van Allen belts — imposing unacceptable radiation levels on crew, sensitive instruments, and film and magnetic tape records. Laboratories and workshops in orbit have certain unique environmental qualities which make the cost of the voyage worthwhile.

The first and most obvious attribute is weightlessness, a condition which can be artificially created on Earth for only brief periods within jet aircraft. Its unlimited availability in space has far reaching implications for the life sciences, physics, metallurgy, chemistry, and dozens of other fields.

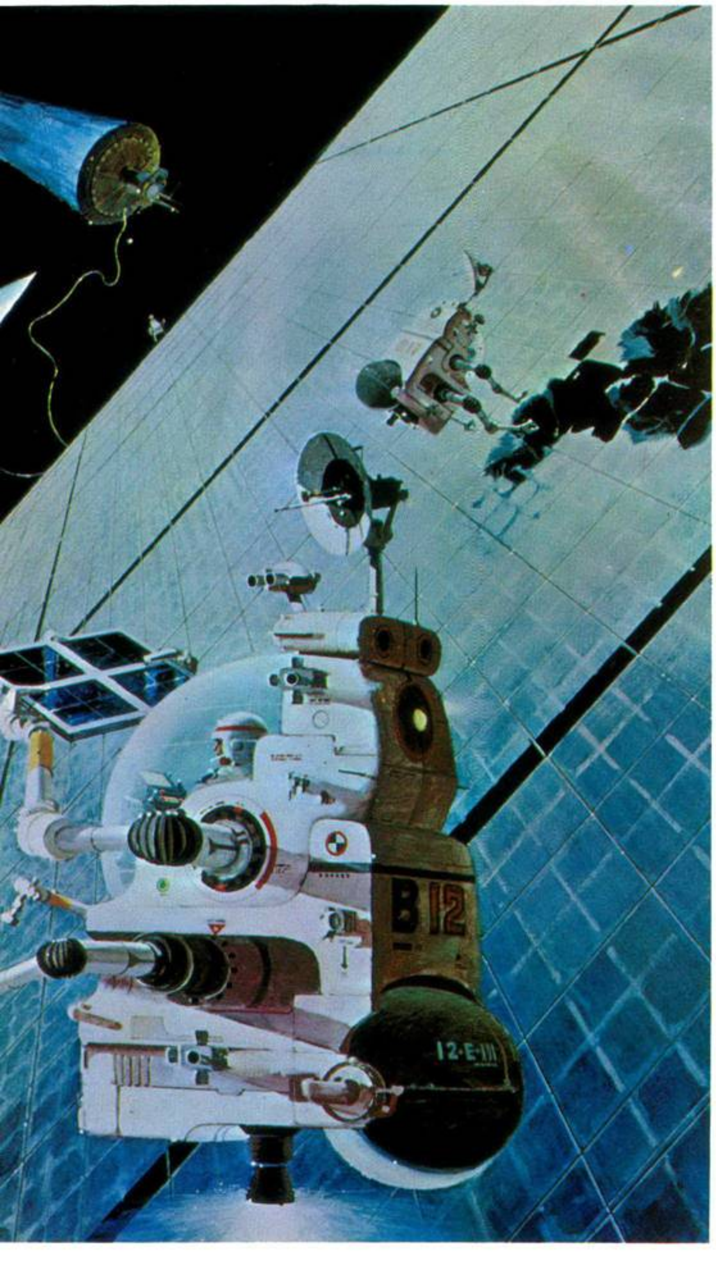
Complex biochemical processes within a living



cell are complicated on Earth by dozens of conflicting effects. In space, many of these distractions can be eliminated, and biological processes carefully examined.

Studying the subtle effects of gravity on Earth is like trying to analyze a whisper in a crowded stadium. Gravitational force is one of the four forces affecting matter. (The others are electromagnetic force, weak nuclear force, and strong nuclear force.) Slight gravitational interactions among subatomic particles will be studied in space, under conditions where Earth's gravitational influence can be canceled.

Weightlessness allows revolutionary metallurgical processes, ranging from "thin films" for computers and solar cells to composite metal/ceramic foams of tremendous strength and low densities. Biological emulsions can grow lifesaving vaccines in a fraction of the time necessary on Earth.



Observations from orbit have revolutionized astronomy in the 1970s. X-rays, ultraviolet and gamma rays, and most infrared rays are blocked out by Earth's atmosphere. Instruments carried into space have just begun revealing new space phenomena occurring in these various spectral regions. But astronomy from space stations will have some drawbacks. The telescope is still within the magnetosphere which blocks certain wavelengths, and Earth fills the sky with radio noise.

Orbital power stations might help solve the energy crisis. Vast squares of solar cells — miles on a side — can collect the powerful solar radiation and convert it to electricity; laser or microwave beams transmit the power to Earth. To insure almost continuous sunlight, as well as continuous contact with fixed ground power-receiving stations, these energy satellites will have to be 20,000 miles high in Earth-synchronous orbits.

There will always be work to do in Earth orbit, and large permanent stations will be established by the end of the 1980s. But these bases will be more than just destinations — they will become way stations on the road to the moon.

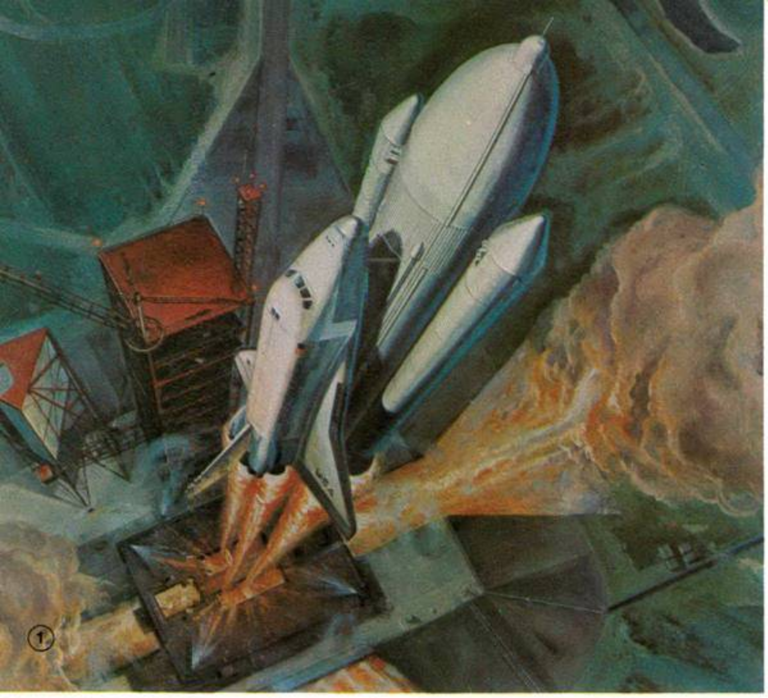
The first operational Earth-moon ferries will probably be built only for flight in space. They will fire their engines for 10 minutes, coast up and out for three days, and fire their engines once more to go into orbit above the moon. There they will be met by other spacecraft designed to land on the moon. Cargo modules can be transferred to the landing craft, which are functional descendants of the Apollo Lunar Modules.

High powered Earth-moon shuttles of the 21st century will skip the lunar orbit transfer and instead land directly on the moon. New engines with power and endurance far beyond anything possible in the Apollo age will fire continuously — not for 10 minutes only, but for hours. Such a rocket thrusting at 1G acceleration (equivalent to the force of gravity on Earth's surface) can cover the Earth-moon route in four hours. These rockets may be nuclear powered and must be highly reliable. Midway through the voyage (two hours out from Earth), the ship will be traveling at more than 40 miles per second — considerably in excess of solar escape velocity. An engine failure at this point would see the ship's momentum carrying it into interstellar space, if rescue craft were not available.

An ancestor of the first Earth-moon ferries is

Nuclear power and solar energy are the keys to making the space environment livable. Here at left is a space city; on the right is a vast solar field that converts sunlight into microwaves and beams the energy to Earth, where it is transformed into electricity — thus providing Earth with an inexhaustible supply of pollution-free power. The one-man work modules at right are repairing meteoroid damage to the solar field. This and the other artwork in this article by Robert McCall are from the lavishly illustrated book *Our World in Space*, published by the New York Graphic Society. See the July 1974 issue for a review.

Artwork by Robert McCall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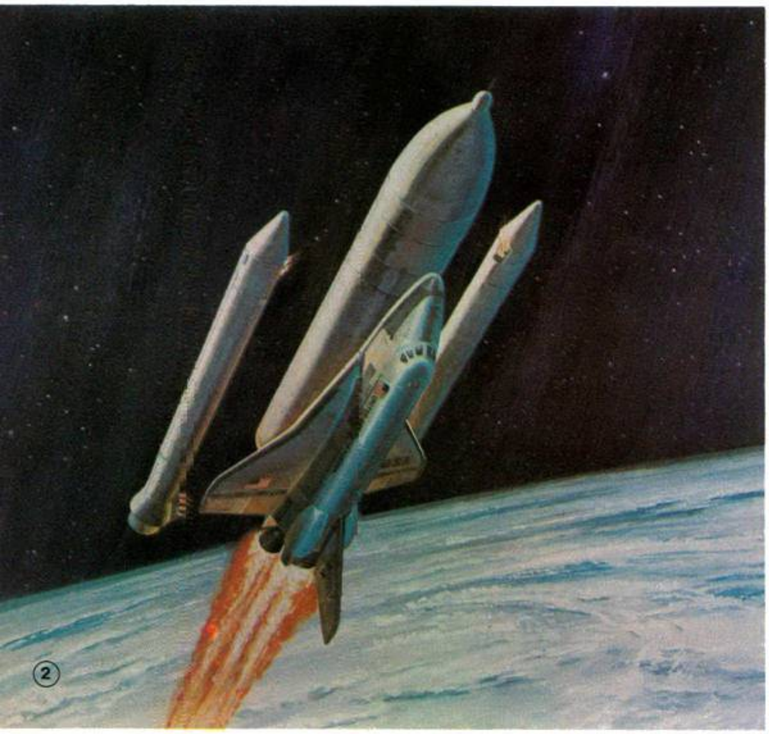
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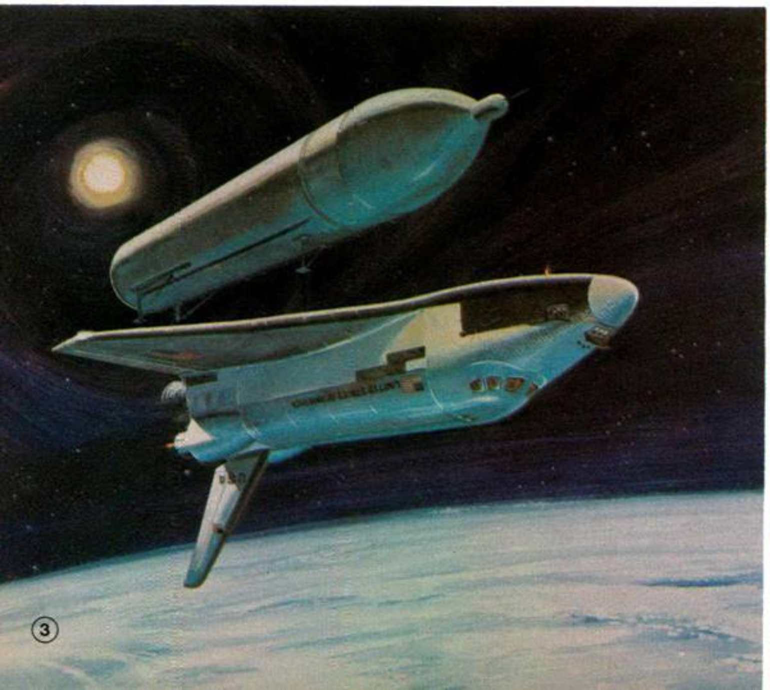
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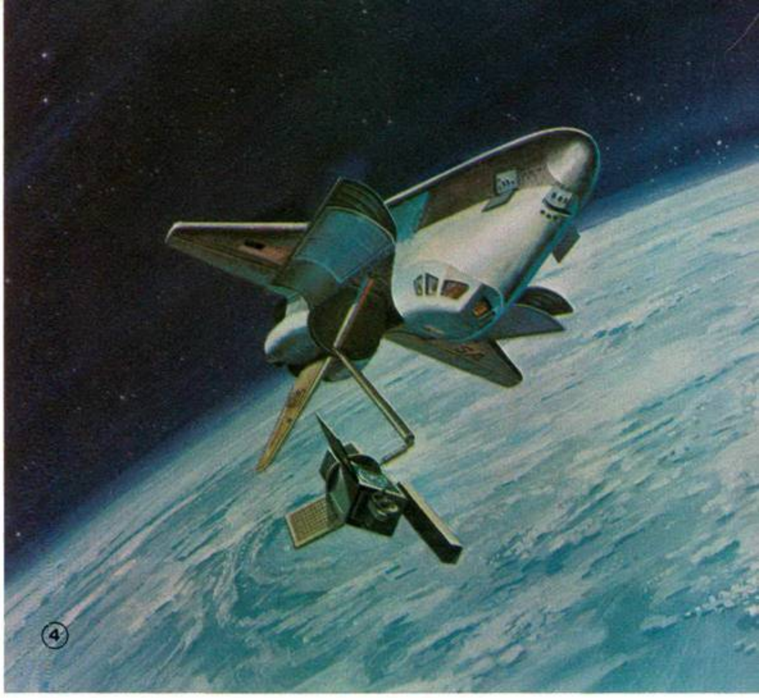
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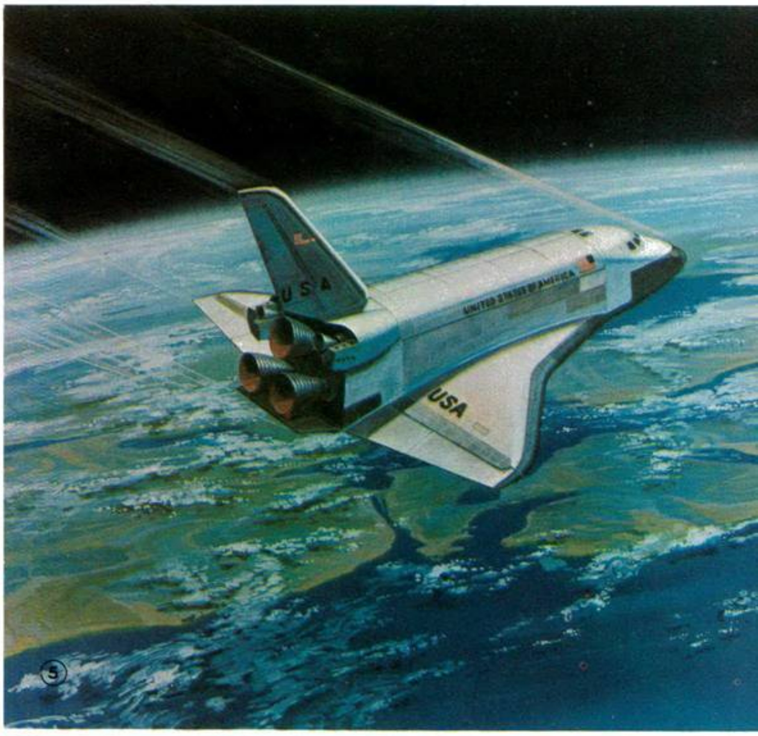
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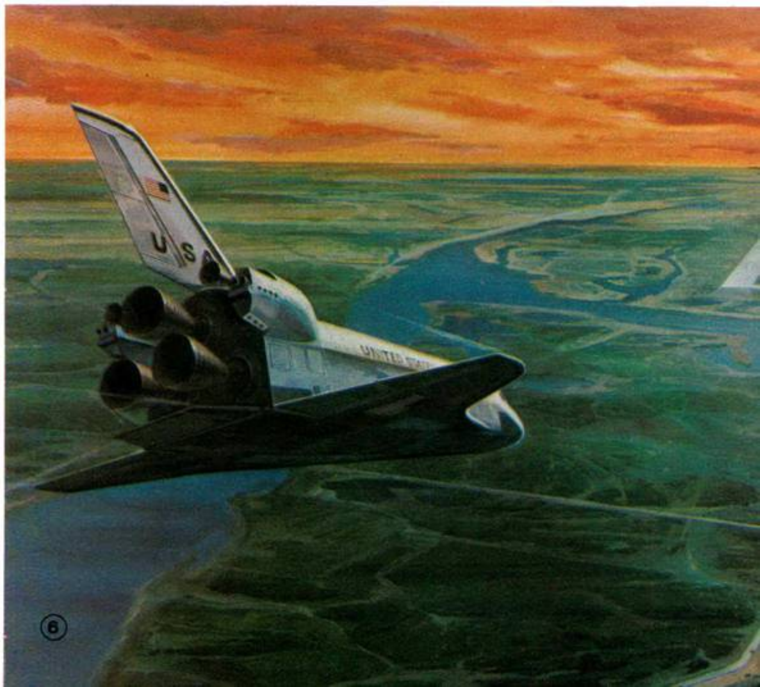
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the NERVA (Nuclear Engine for Rocket Vehicle Applications) — a nuclear rocket engine developed by NASA in the 1960s. Although NERVA was canceled by economy measures after the Apollo landings ended, advanced nuclear rockets will build on NERVA technology.

Extensive rocket traffic in the vicinity of the moon in the 1990s will dump tons of burned fuels into the tenuous lunar atmosphere daily. However, there will be no long range pollution problem since each month the sun's heat will accelerate most of the particles to lunar escape velocity, purifying the moon's scant atmosphere.

For the foreseeable future, space rockets will continue deriving their thrust from the action-reaction effect of expelling particles behind them. The faster the particles are expelled, the higher the resulting acceleration. Particles can be generated by cold gas from a storage tank, combustion products of burned fuels and oxidizers, ions expelled by electromagnetic fields, or superheated material expanding after passage through a high temperature atomic reactor. One concept of the 1960s envisaged small atomic bombs set off every few seconds inside a giant thrust chamber.

These designs were beyond the technological capabilities of space engineers of the 1960s, but most will be practical within three decades. With a superrocket which can maintain a 1G acceleration for days on end, the flight time from Earth to Mars will be 50 hours. Jupiter will lie four days beyond.

Launching ships from the lunar surface may someday be done without rockets. Jules Verne's "space gun" may become a reality on the moon, with electricity rather than gunpowder providing the impulse. A 20 mile long horizontal ramp can electromagnetically accelerate payloads to sufficient velocities for escaping the moon. The moon's low gravity, lack of air drag, and availability of abundant solar-electrical power will make this scheme attractive. Through such an economical launching system, the moon — instead of Earth — will become man's spaceport to the solar system.

Will men or machines have the primary task of exploring neighboring worlds? Mars' low gravity and thin atmosphere would not be much more of a challenge to manned landing than the moon was. But exotic and extremely complex vehicles would be required for carrying explorers to the smothering furnace of Venus' surface or into the crushing, hurricane-like cloud decks of Jupiter and the other gas giant worlds. On most planets, robots would be far more adaptable.

Nevertheless, a fierce debate has been raging between the advocates of manned versus unmanned space exploration. Some scientists claim that robots are cheaper than manned flights and can be sent on suicide missions. Astronauts are more flexible, the other school points out, and can react to unforeseen opportunities and emergencies.

Several points can be made to help clear up this conflict. First, there is no such thing as "unmanned" space exploration. The men are either along with the probe — examining the environment and manipulating the instruments — or they are back on Earth, receiving the data indirectly and sending new commands to the probe by radio.

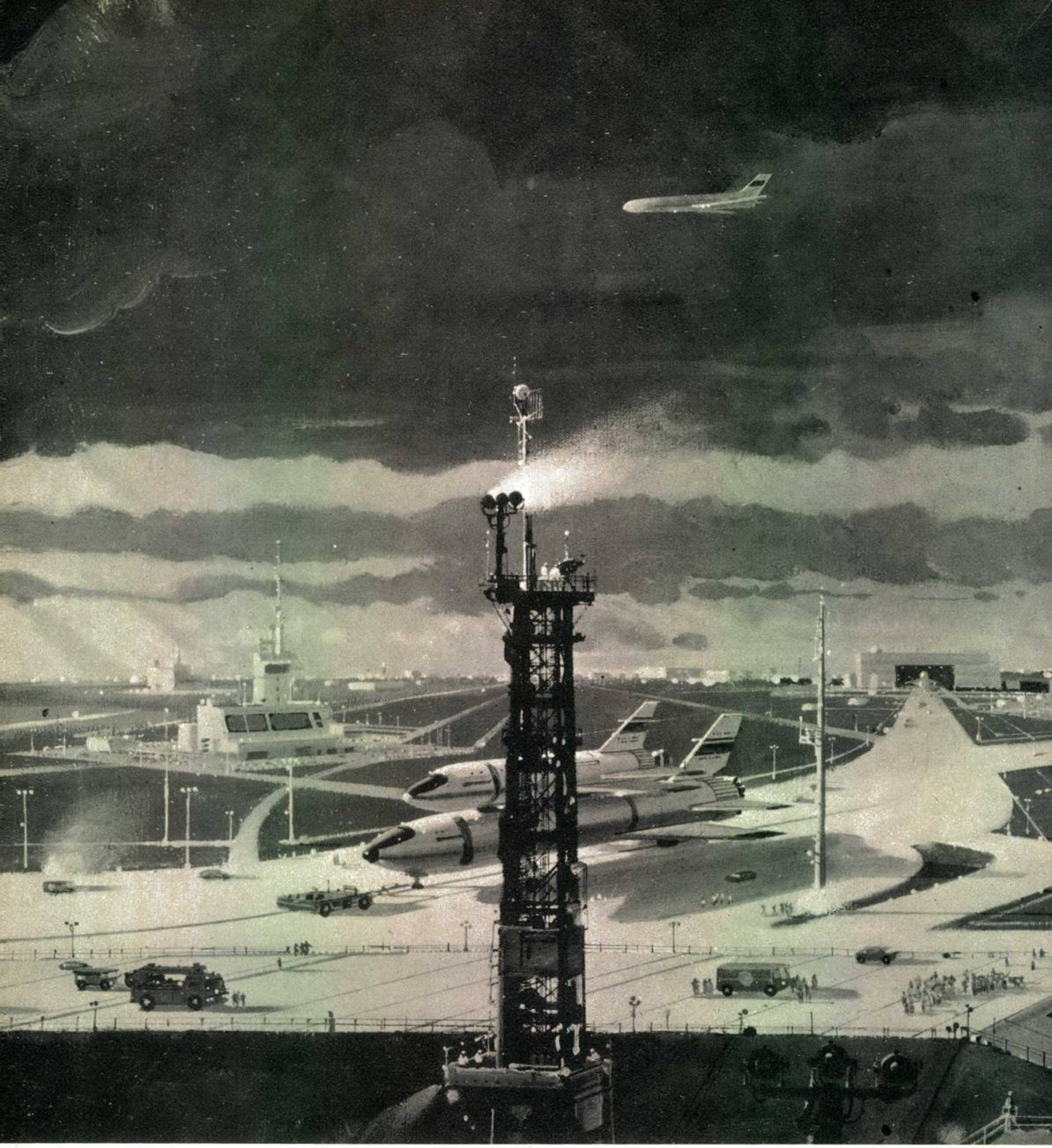
In many cases, simple automatic devices can sufficiently carry out the intended mission. If the types of measurements are known in advance, if the volume of data is not too large, and if rapid response to new situations is not necessary, then unique human capabilities may not be called for. If a round trip voyage is too expensive or not technologically feasible, the obvious choice is an expendable robot.

But most exploration after the first trail-blazing probes requires a more intelligent selection of just what data is important, what observations must be made, and what actions must be taken under varying conditions. This can be done by having a man on board or by using a remote control system. If the action takes place at one location while the human operator is at another, this is called *telefactoring* (work at a distance).

The human controller on Earth must have displays telling him what is happening around the robot; he must also have controls for transmitting commands to alter the robot's course of action. The commands must reach the robot soon enough to be

During the 1980s, America's Space Shuttle will revolutionize space travel — making it a commonplace event as missions almost weekly carry civilian scientists and a variety of payloads into Earth orbit. A typical shuttle flight begins with (1) the familiar fiery liftoff from launch facilities at the Kennedy Space Center or Vandenberg Air Force Base. Two solid fuel boosters and the shuttle orbiter's three liquid oxygen/liquid hydrogen fueled engines propel the vehicle skyward with four million pounds of thrust. (2) Two minutes later, the shuttle breaks 3,000 m.p.h. and jettisons its burned out solid fuel boosters 27 miles above Earth. The two radio beacon-equipped cylinders fall into the ocean and are recovered and refurbished for future flights. (3) Within 10 minutes, the spacecraft enters an elliptical 57 by 115 mile orbit. Soon after, the orbiter discards the now empty external fuel tank beneath its body. Most of the main tank disintegrates during re-entry into the atmosphere; remaining fragments are targeted to crash into a sparsely traveled area of the Indian Ocean. (4) Smaller rockets aboard the airplane-like orbiter next insert it into a stable, circular orbit which — depending on the mission — can range from 100 to 600 miles altitude. Now the shuttle's four-man flight crew settles down to business. From a control station on the shuttle flight deck, a payload specialist opens two large cargo bay doors and deposits satellites in orbit or retrieves them for repair. On other missions, a six-man laboratory housed within the 60 foot long cargo bay permits scientific experiments in the space environment. (5) After up to 30 days in orbit, the shuttle plunges back into Earth's atmosphere at 17,000 m.p.h. Special heat ablative material protects crew and passengers from air friction temperatures approaching 2,000 to 3,000 degrees Fahrenheit. (6) Once a multimillion pound thrust rocket, the shuttle now glides powerlessly toward a 10,000 foot runway at either of the two launch sites. The pilots, assisted by an onboard computer, streak onto the landing strip at 215 m.p.h. (faster than commercial jetliners). Fourteen days later the orbiter will be back on the pad, ready for another mission.

Rockwell International Artwork

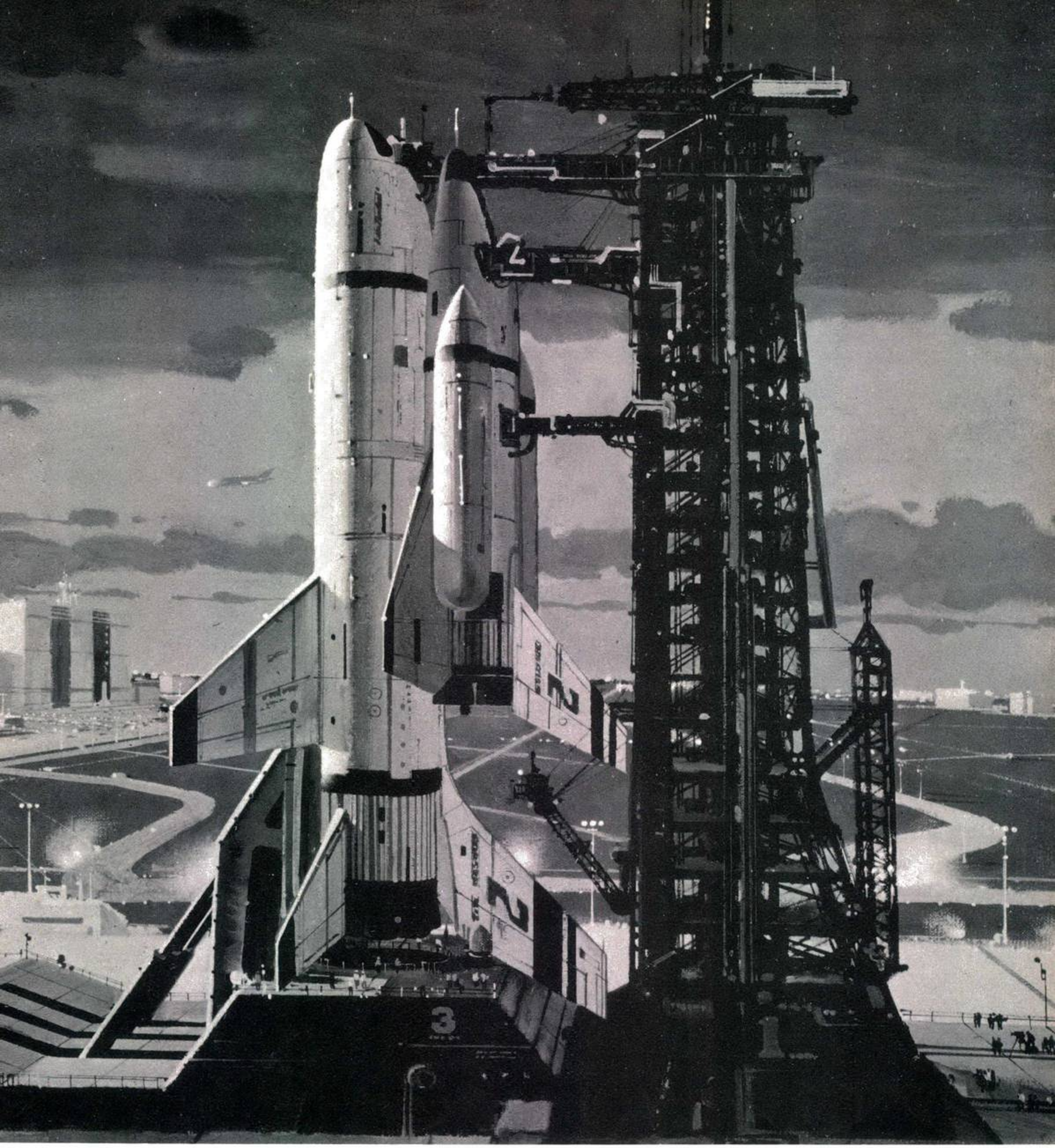


Artwork by Robert McCall

The Space Shuttle will combine the advantages of airplane and spacecraft — flying into space and returning to Earth to make future flights — resulting in enormous savings of money and time. This rendering shows Kennedy Spaceport as it might appear near the end of the century. At right is an advanced shuttle system ready for launch with the small orbiter on the back of the giant manned booster. Another shuttle is being moved up to its launching pad. The orbiter will be essentially a common carrier; its passengers will no longer be required to pass stringent standards for space flight. Unlike the shuttle booster system now in preparation (see illustration, page 22), this sytem will be totally reusable.

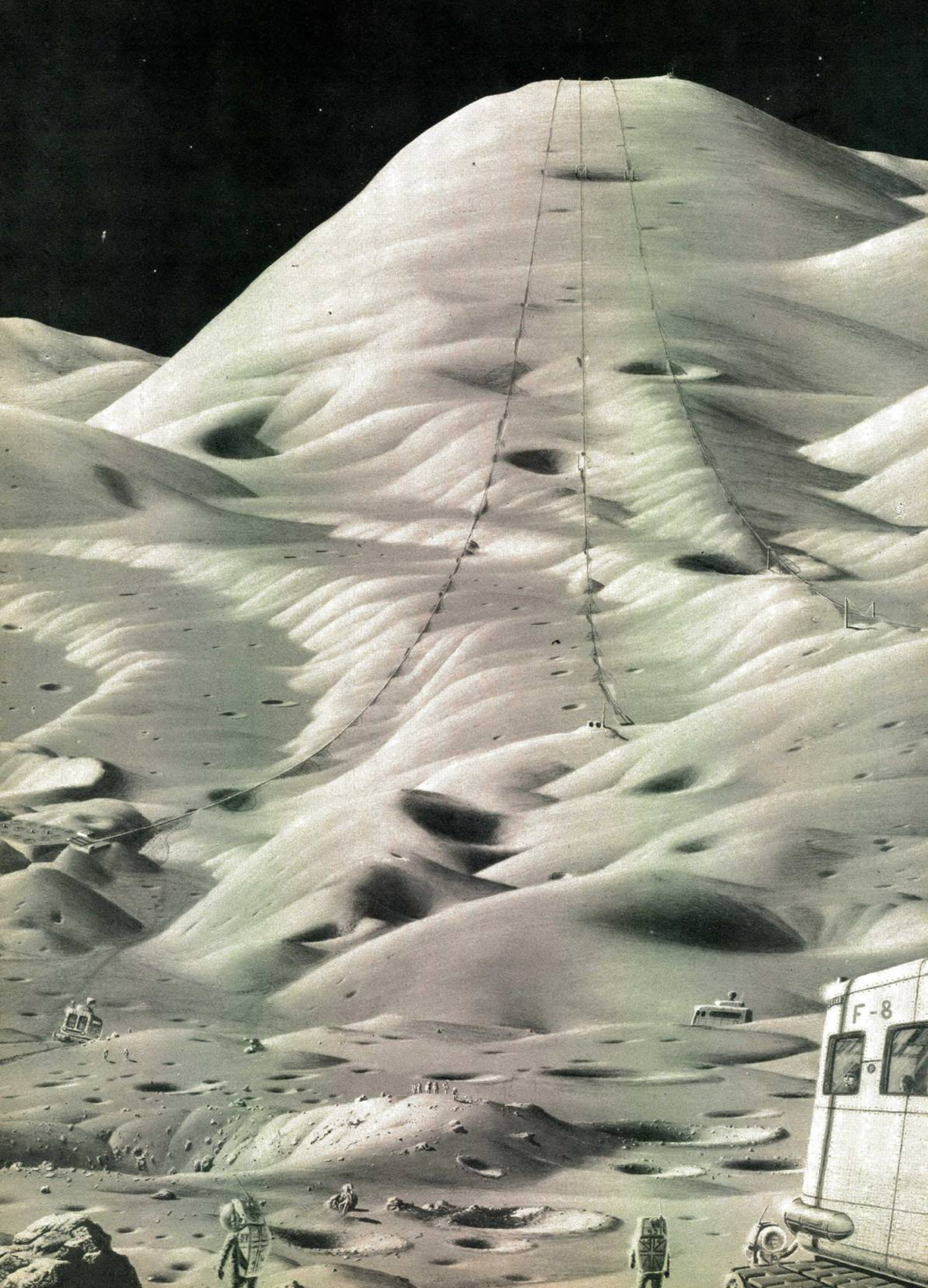
useful.

For example, the Russian "Lunakhod" wheeled moon jeep rolls across the lunar surface a quarter of a million miles from the "driver" back on Earth. On a television screen he monitors the view in front of the robot, and with a simple steering wheel he sends new directions to guide the jeep around obstacles. He activates the robot's claw arm to pick up rock samples and bring them close to the television



camera for detailed examination. The reaction time of the driver is ultimately limited by the round trip time for the radio signals. Traveling at the speed of light, this imposes a 2-1/2 second delay with moon robots controlled from Earth. If the jeep is not going too fast, this still gives ground controllers plenty of time to spot obstructions and relay corrective actions.

But this remote control scheme cannot work on Mars or further away, since the delay in reaction time is too great. Even at the closest distance between Mars and Earth, the round trip for a radio signal exceeds six minutes. A remote control team on Earth might watch helplessly as their "Marsokhod" approaches a cliff edge; the men know that their "stop" command will not reach the robot for another 10 minutes, during which time it will topple over the edge to destruction.



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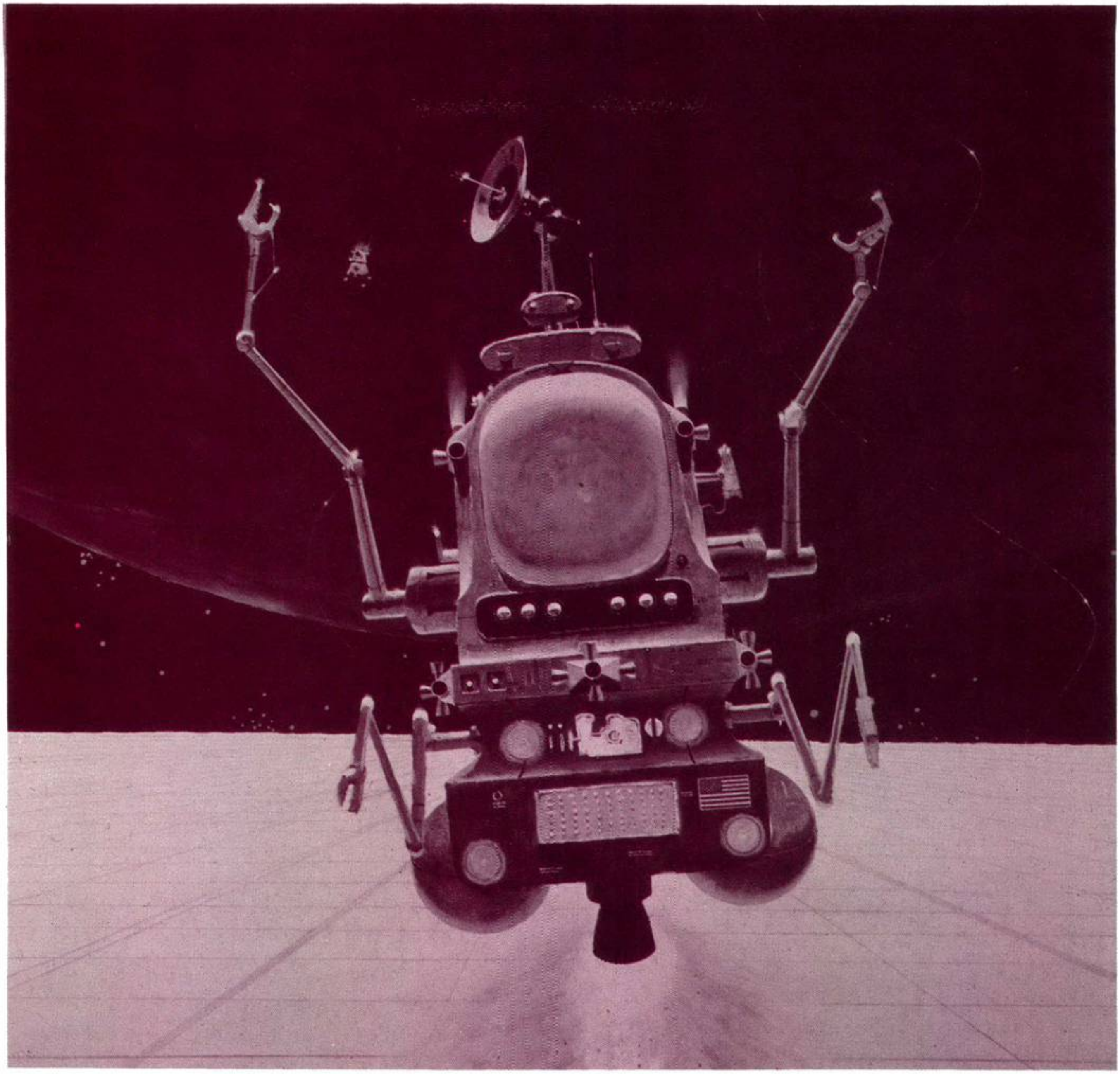


Artwork by Robert McCall

The space robot will likely become commonplace once we begin construction projects in space. The robot's weird appendages, designed to perform many tasks, are operated by one man seated safely behind a control console at some distant base. Through television and exotic telemetry, he can manipulate the robot with great precision.

The answer, of course, is to keep your control delay short (stay close by, or in, the vehicle), or to put some of the control intelligence in the remote vehicle. A small computer could be programmed to recognize some types of dangerous situations and stop itself until it got detailed instructions from Earth. Such computers have already been built; since the early 1970s, they have been steering little carts through a room filled with obstacles. Similar electronic computers will provide on-site intelligence for many space probes of the future.

Spacecraft launches from the moon will be relatively simple compared to the same process from Earth's surface. With lunar gravity only 1/6 that on Earth, the moon launch system is simply a ramp running up the side of a mountain or crater wall. Magnetic levitation systems propel a space vehicle directly into orbit or to Earth in slingshot fashion.

Artwork by Adolf Schaller

On distant planets, robot vehicles will continue serving men. They will probe dangerous regions, stand watch at isolated outposts, and go where men cannot. They will be guided by humans through remote control or by instructions stored in their own computer brains. The exploration of space will continue to be manned exploration. Man will continue to use automatic vehicles to extend his senses to the solar system's far fringes, and some day to neighboring stars.

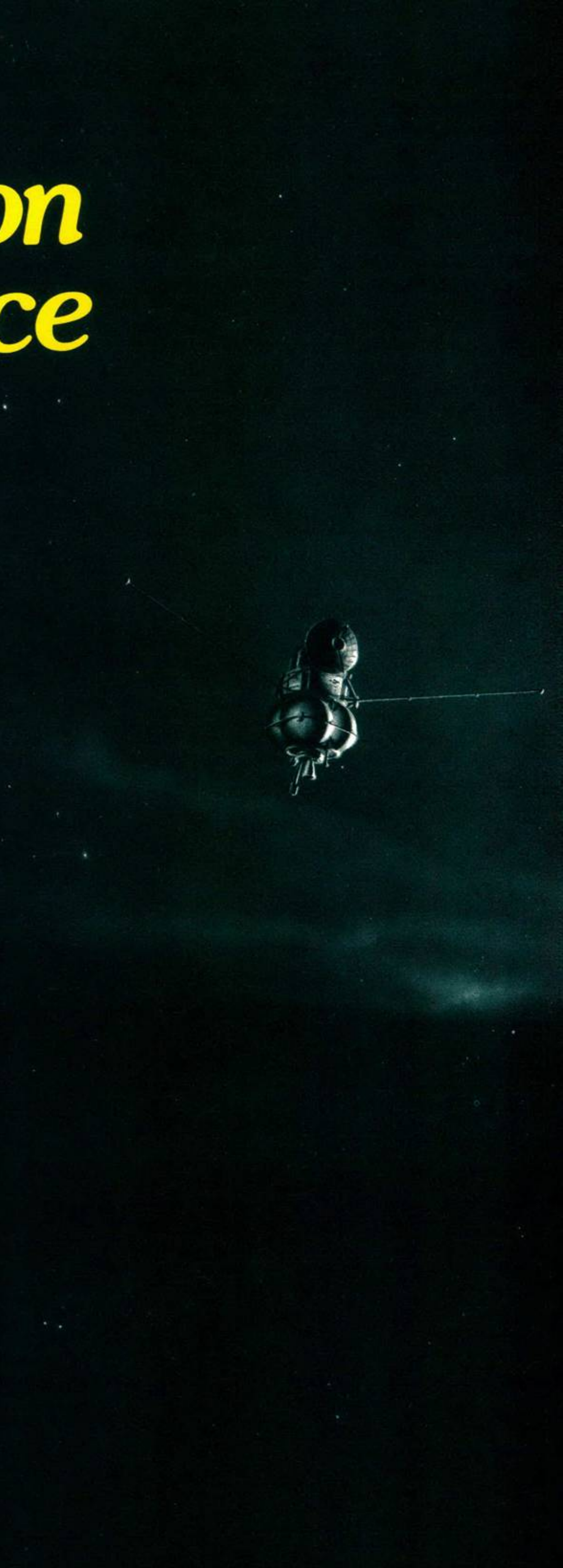
Comet Exploration from Space

by Eric Burgess

Several space projects have ended with spare spacecraft — test spacecraft that were updated to flight status in case the first spacecraft should founder into the Atlantic because of a launch malfunction. Often these spacecraft are "mothballed" while space officials ponder proposals for their use. Two such examples are a spare Pioneer class spacecraft of the type that successfully rendezvoused with Jupiter and transmitted unprecedented close-ups of that planet and its major satellites, and a Mariner class of the type that provided the first look at Venus' ultraviolet clouds and the cratered face of Mercury.

So far there has been no decision on what to do with these sophisticated space machines. They idly languish, waiting for a worthwhile task. But space scientists are not idle; they have supplied NASA with many proposals for using the spacecraft. One mission (proposed by Kerry T. Nock of the Jet Propulsion Laboratory in Pasadena, Calif.) involves using the Mariner spacecraft for a comet flyby. The target would be comet d'Arrest, which will dash between the orbits of Earth and Mars in August 1976. To meet with d'Arrest, Mariner would have to be launched in June 1976 for an encounter in August just after the comet's *perihelion* (closest approach to the sun).

D'Arrest is a faint, short-period comet which has been observed on 12 returns to the sun since its 1851 discovery. The comet appears diffuse, with very little evidence of condensation and dust. Like most comets, d'Arrest probably originally came from a comet cloud (first hypothesized by Dutch astronomer Jan Oort). Comprised of countless chunks of frozen gas and dust, the cloud might exist halfway between the sun and its nearest star. A gravitational tug from a bypassing star could occasionally launch one of



A space probe approaches the mysterious realm of a comet's head, or coma, in a future space rendezvous. A battery of instruments probes the comet's tenuous atmosphere as narrow angle television cameras attempt to resolve its tiny nucleus — the fountainhead of spectacular streamers of gas and dust. With relatively modest funding, such a dramatic comet intercept could occur next year. We already have the spacecraft, instrumentation, booster and know-how.

Artwork by Adolf Schaller

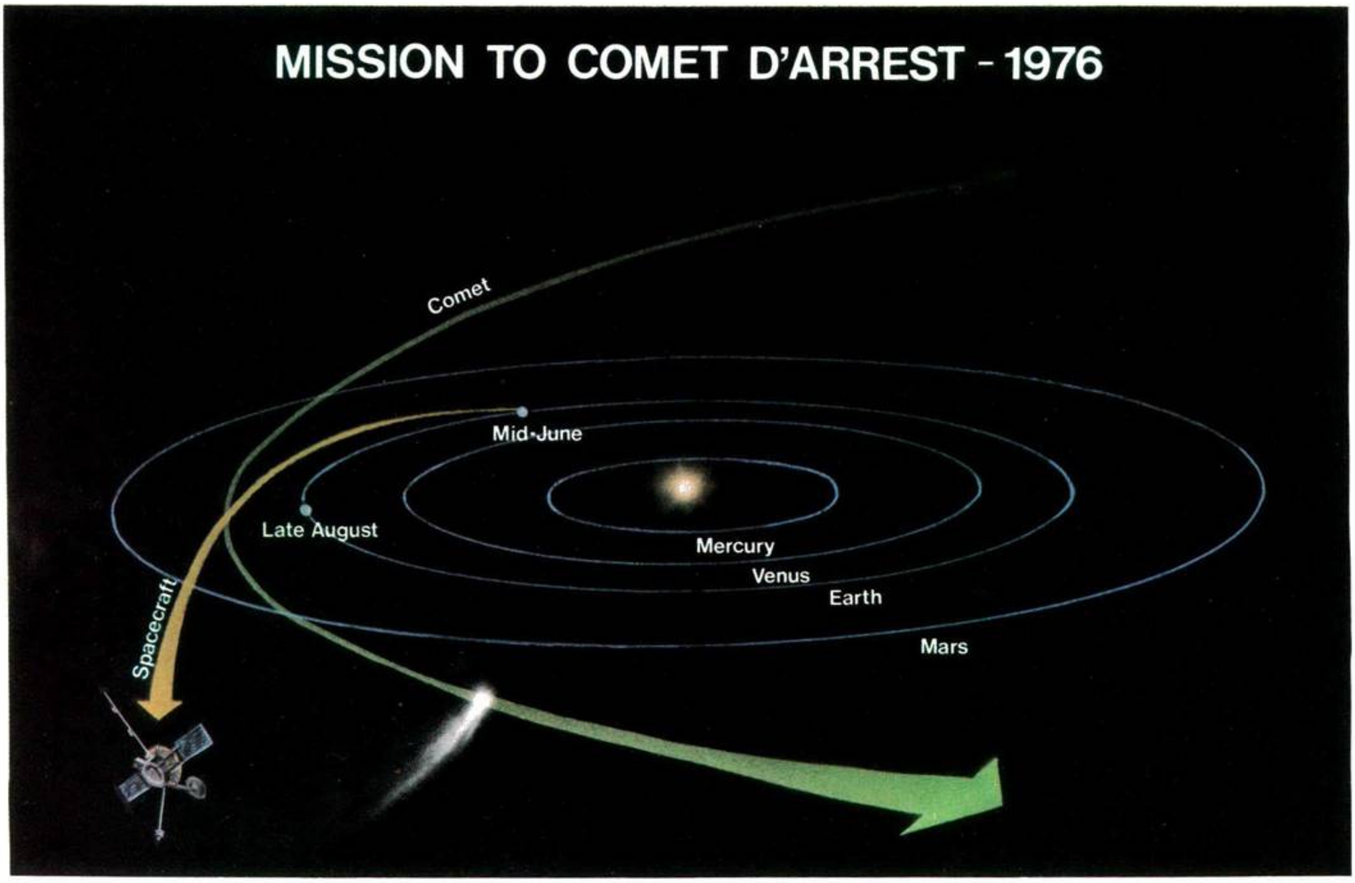
these flying icebergs on a long sunward journey.

A comet only becomes spectacular when the sun's energy begins boiling material off the tiny, solid nucleus. A gaseous shell, or coma, envelops the nucleus as the solar wind generates a multimillion mile long tail of dust and fluorescing gases behind the coma. On past returns, d'Arrest's coma was about 40,000 miles in diameter — expanding to 150,000 miles about 60 days after perihelion. A chance encounter between Jupiter and d'Arrest likely modified the comet's path making it one of about 100 known short-period comets. D'Arrest is considered particularly interesting because it seems a relatively young object, probably still possessing much volatile material within its nucleus. The comet also has a fairly stable and predictable orbit.

At present there are abyssmal holes in theories about these "ambassadors from the stars" (as the ancient Chinese called them). Fundamental information is lacking, despite centuries of comet observations. For example, the size of particles within comets is in doubt by three orders of magnitude. Comets' bright tails suggest fine dust is streaming off the nucleus. But meteor showers that occur when Earth passes through the solar-orbiting debris left behind by a regular appearing comet implies that pea size grains or larger must also be present.

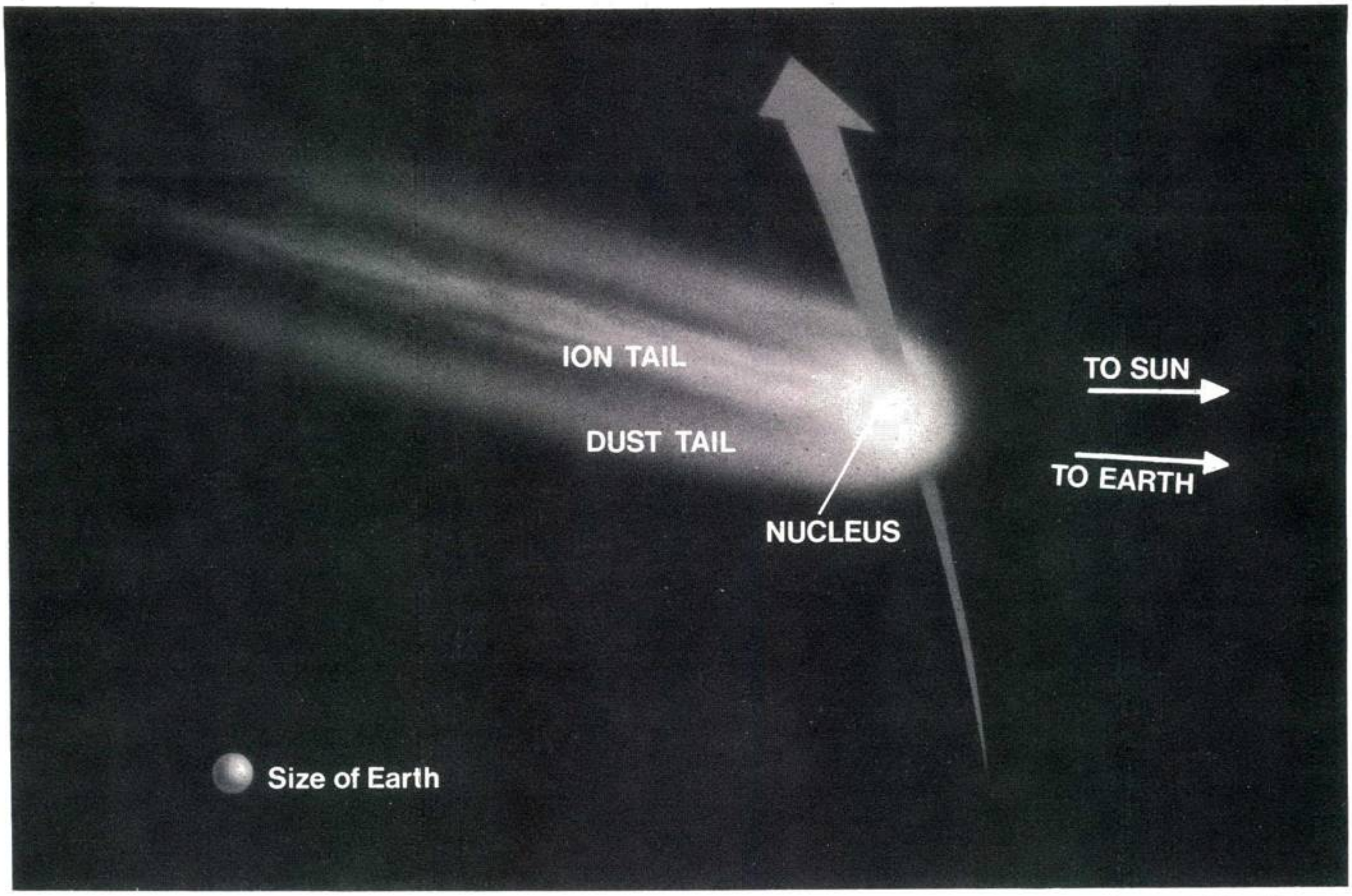
What is the chemistry of a comet? In comets' tenuous ion atmospheres, hydroxyl and cyanogen radicals (fragments of larger molecules) — among others — have been detected. But estimates of their abundance may be off by 10 to 100 times. The "parent" molecules of some radicals have also been detected, like water and methyl cyanide; however, scientists are not sure these represent major constituents of the nucleus. Some frozen gases in the nucleus are not expected to have emission lines in observable regions of the spectrum. They can only be found through taking samples within the comet's coma, tail, and regions outside the visible coma.

Although many astronomers agree that comets possess nuclei, some doubt still lingers. Oxford astronomer Raymond Lyttleton argues that a collection of loose particles occupies a comet's center instead of a solid, "dirty snowball". The problem is that nuclei have never been observed from Earth because of their extremely small size and faintness. Nuclei account for no more than one percent of the



Artwork by Victor Costanzo

Plans for intercepting comet d'Arrest call for launching a Mariner spacecraft around June 14, 1976. Mariner chases the comet for 75 to 103 days as it approaches perihelion (closest approach to the sun). Shortly preceding or following the comet's perihelion, Mariner enters the comet's environment and spends roughly four days drifting through its hydrogen corona, bow shock and coma before continuing on into solar orbit. Comet d'Arrest's trajectory is especially suitable for a flyby mission. The comet's perihelion falls between the orbits of Earth and Mars, and d'Arrest's closest approach to Earth (about 14 million miles) coincidentally occurs near that same time. D'Arrest's path places it in the nighttime sky during the weeks preceding perihelion, allowing ground based observations to assist in Mariner's navigation.



Artwork by Victor Costanzo

Mariner's encounter with comet d'Arrest begins about one million miles from the nucleus. Traveling at a relative speed of nine miles per second, the probe spends two days coasting through the comet's invisible hydrogen corona and bow shock. Next, in only 2-1/2 hours, Mariner streaks through d'Arrest's bright gaseous coma. During that time the spacecraft may come within 600 miles of the tiny, solid nucleus. For comparison, Earth's size is shown at the lower left.

total brightness of each comet, and probably measure between one and six miles in diameter.

How comets interact with the *solar wind* (the constant stream of charged particles from the sun) is unknown. There are at least two possible models. One model suggests that when the solar wind strikes a comet, charged particles abruptly decelerate from their supersonic (not to be confused with the speed of sound in air) flow of about 400 miles per second to a subsonic flow of 200 miles per second. In a way analogous to the build-up of a bow wave in front of a moving ship, this collision should set up a shock front where particles and solar magnetic energy collect in increasing density. On the other side of this bow shock, particles would flow at subsonic speeds.

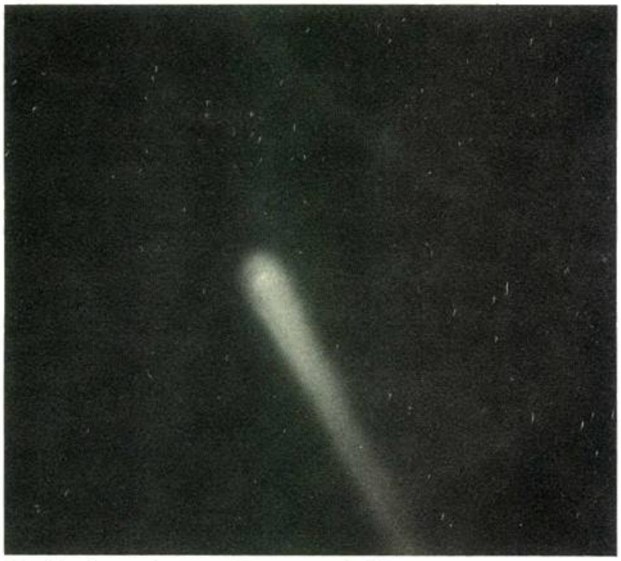
The other theory suggests that the transition from supersonic to subsonic flow occurs over a very wide region, not as a shock front. Swedish physicist H. L. Alfven suggested in 1957 that magnetic fields play a key role in the structure and behavior of comets. The magnetic field of the comet will influence the interaction with the solar wind. Such a field cannot be measured from Earth.

A mission to comet d'Arrest would have three primary objectives: The spacecraft would take direct physical measurements of the comet's composition, search for a solid nucleus, and measure the comet's interactions with the solar wind and the interplanetary medium.

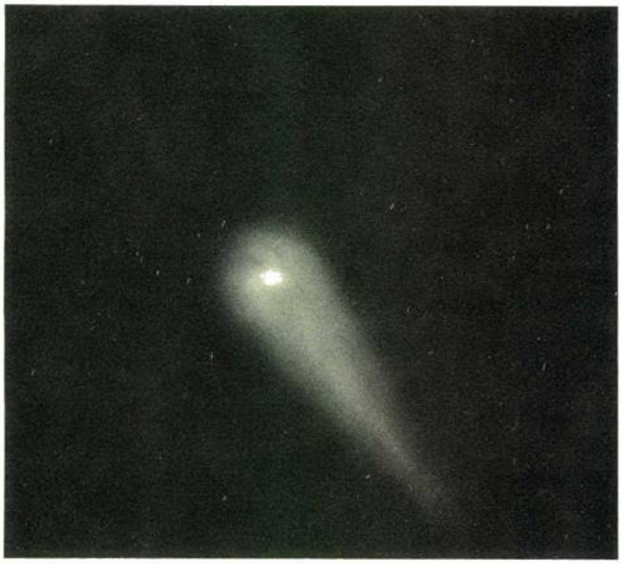
An important consideration in any mission to a comet — and there have been others proposed using other spacecraft — is the ability to be able to make concurrent observations of the comet from Earth and the spacecraft. Ideally, several hours of Earth based observations should be available each night during the encounter period. Comet d'Arrest fits this requirement; it will be favorably situated for observation from Earth in 1976 at the time of the spacecraft's encounter, being only 13 to 18 million miles away and about sixth magnitude. Moreover, the spacecraft will be able to observe comet from 13 days before to 23 days after perihelion when the comet is being strongly affected by solar radiation and solar wind.

Since the mission would be a relatively short one, it would not cost much in mission support time. It is very cost effective for the scientific return. The entire exploration would last between 75 and 106 days, depending on how close to the opening of the launch "window" on May 22 the actual launching could take place. The window closes on June 28.

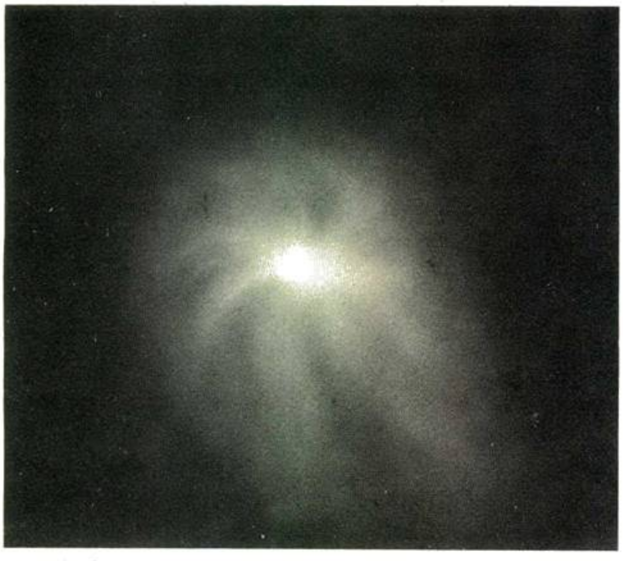
Encounter Profile for Comet d'Arrest Flyby



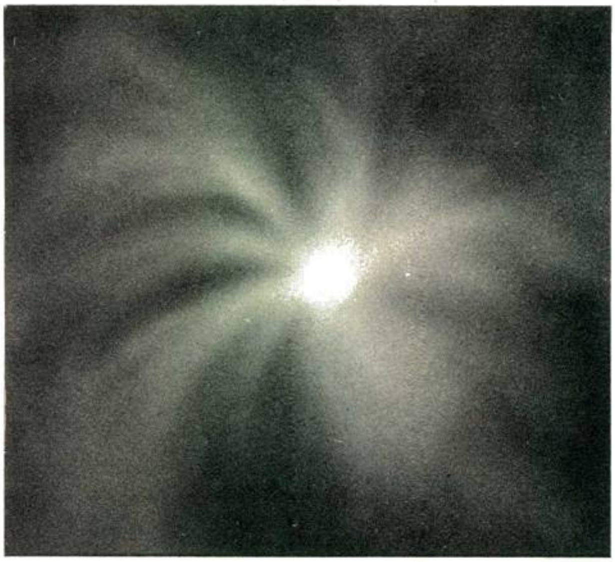
① detect comet coma with spacecraft TV
time to nucleus: 20 days
distance to nucleus: 12 million miles



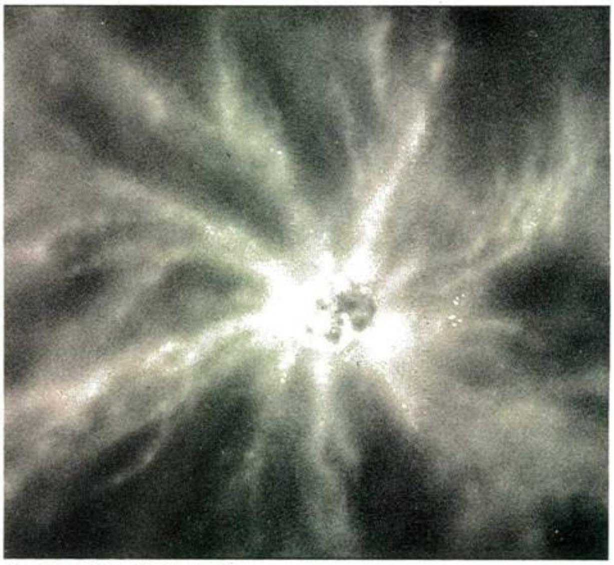
② detect comet nucleus
time to nucleus: 10 days
distance to nucleus: 6 million miles



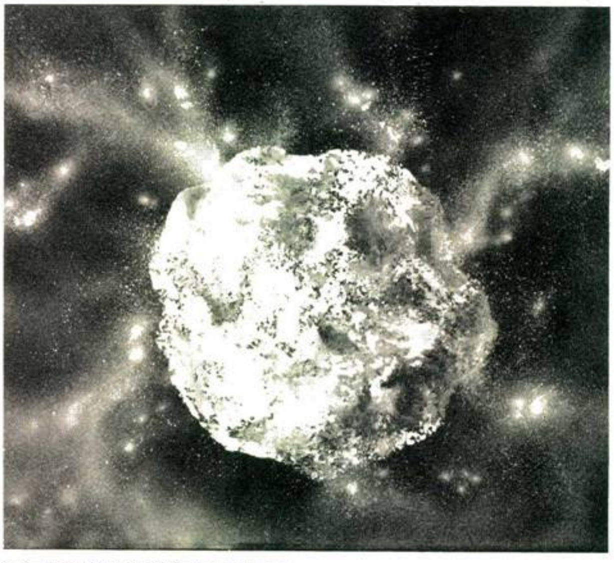
③ enter hydrogen corona
time to nucleus: 2 days
distance to nucleus: 1 million miles



④ enter coma
time to nucleus: 70 minutes
distance to nucleus: 30,000 miles



⑤ resolve nucleus detail
time to nucleus: 10 minutes
distance to nucleus: 4,800 miles



⑥ closest approach to nucleus
distance to nucleus: 600 miles

Contrary to missions to planets whose orbits are well known, a comet mission has orbital uncertainties since comets are perturbed by the planets. The orbit of the comet during this perihelion passage must be accurately determined before the spacecraft is launched. Short-period comets are notorious for their interactions with Jupiter, and d'Arrest is no exception. Jupiter recently changed the comet's ephemeris. Now the period of the comet is 6.6 years; the time of perihelion is Aug. 12, 1976, and the perihelion distance is 108,206,000 miles. But until the comet has been rediscovered and tracked sufficiently, the ephemeris cannot be accepted absolutely for 1976.

Unpredictable but relatively slight changes are likely caused by gases boiling off the comet's nucleus. They produce a small reaction force which accelerates or decelerates the comet by a few inches per second. Such a weak but constant thrust over a period of a few weeks can make the comet's real position significantly different from its predicted path. Continuous comparison between Earth based and spacecraft observations will allow astronomers to keep a close track on changes in d'Arrest's orbit.

Here is a profile of the d'Arrest mission:

Early in 1976 — when astronomers have determined that the comet is following its expected orbit and has not been further perturbed by the outer planets — the Mariner 10 backup spacecraft can be launched to navigate within 600 to 1,800 miles of the comet's nucleus. Three trajectory correction maneuvers are likely: The first corrects for launching injection errors; the second corrects for any updating of the comet's trajectory following launch as a result of additional measurements made by the comet observation network, and the final maneuver — made just before encounter — is based on optical approach guidance achieved by television imaging of the comet.

During encounter, the instruments on board the Mariner spacecraft would be expected to detect the coma with television imaging at a distance of 12 million miles, about 20 days before closest approach. Ten days later the nucleus should be resolved via TV. Two days before closest approach, Mariner enters the comet's hydrogen corona, and soon thereafter passes through the bow shock — if it exists.

The spacecraft next enters the coma about one hour before closest approach. One of the trickiest and most crucial elements of the mission now begins. A narrow angle, high resolution television camera attempts to track the tiny nucleus as Mariner streaks through the coma at nine miles per second. A three mile diameter nucleus may fill almost 2/3 of the camera's field of view if Mariner flies within 600 miles of the starlike object.

While the spacecraft transmits images of the comet, other sceintific instruments on Mariner probe into the comet's material and structure. A plasma science experiment plots electron and ion densities, velocities and temperatures across the bow shock, in the transition region, the coma, and the areas close to the nucleus. A magnetometer measures the comet's magnetic field. A solid particle (meteoroid) detector investigates the range of sizes of nucleus debris to check if comets are the source of meteoroids in the solar system. "Particle collisons are the biggest safety hazard to Mariner," Nock points out. "In fact, the spacecraft might not survive that hazard."

An ultraviolet spectrometer searches for emissions of hydrogen, helium, carbon, oxygen, neon and argon as a mass spectrometer identifies coma and near-nucleus chemistry by taking the mass of molecules within the comet's atmosphere. If, as some theories suggest, comets were leftover material from the original cloud of dust and gas that condensed into the sun and planets, comets' chemical makeup is a deepfreeze sample of the primordial solar nebula.

"When we go to the planets, we find that they have been so altered by processes occurring since creation — like winds, vulcanism, oxidation — that all of the solar system's original history is erased," emphasizes Nock. "So we look to the comets and asteroids, the smaller bodies that can't have all these forces, as the places where we may find some of that original material."

But, for this mission, time is rapidly running out. Comet d'Arrest will not wait for mankind. To meet the launch window deadline, the project would have to start immediately. The next opportunity to intercept short-period comets will be in 1977 for comet Grigg-Skjellerup or 1979 for comet Giacobini-Zinner. For these missions, a new spacecraft with a spin-scan imaging system has been proposed (based on the Interplanetary Monitoring Platform class of spacecraft). Neither of these comets will be as favorably placed for exploration as d'Arrest. After that, a 1980 flight to comet Encke is being considered. However, at the time of Encke flyby, both spacecraft and comet will be four times farther away than d'Arrest will be in 1976.

If the nation does not decide to go ahead within the next month or so, we will have missed a unique and extremely economical opportunity to explore a comet. The $40 million price tag is about half the cost of one of the cheapest interplanetary missions yet flown (the 1964 Mariner flyby of Mars) — and less than half of the money spent each year convincing Americans that individual brands of aspirin have unique healing properties over other brands! It is, indeed, small price to pay for a first look at a relic of creation.

This mission profile outlines several important events comprising Mariner's flyby of comet d'Arrest. Each frame approximates television transmissions that scientists should receive from the spacecraft's cameras during the last days preceding closest encounter with d'Arrest's nucleus. Highlight of the flyby would be the first detailed pictures of the shape and surface structure of a comet nucleus.

Artwork by Victor Costanzo

Major Moon Eclipse Highlights May Sky Show

The best lunar eclipse in many years makes Saturday, May 24 a date to mark on every calendar in your home. Around midnight that night a gorgeous spectacle will unfold as told in Gazer's Gazette this issue.

Elsewhere in May skies, Mercury makes its best appearance of the year and Venus continues to brighten spring evenings.

Eclipses

Two eclipses occur this month: One is the lunar eclipse fully detailed in Gazer's Gazette, while the other is a partial solar eclipse visible only from Europe. Two eclipses in one month are a common phenomenon because the circumstances causing the eclipses — the alignment of Earth, moon and sun — exist for several weeks at approximately six month intervals.

Venus

Hovering like a brilliant white beacon, Venus is in its prime — high above the western horizon at dusk. The brightest planet remains visible for three hours after sunset, slowly sinking into the west as the night progresses.

Venus decreases its distance from Earth from 100 to 79 million miles during May. The same interval sees its telescopic appearance change from a 16 second of arc, 72 percent illuminated gibbous to a 20 second diameter, 60 percent phase.

Those changes in size, shape and distance result in a 20 percent brightness increase this month from magnitude -3.6 to -3.8. Observing tips and additional information were given in last month's Gazer's Gazette.

Mercury

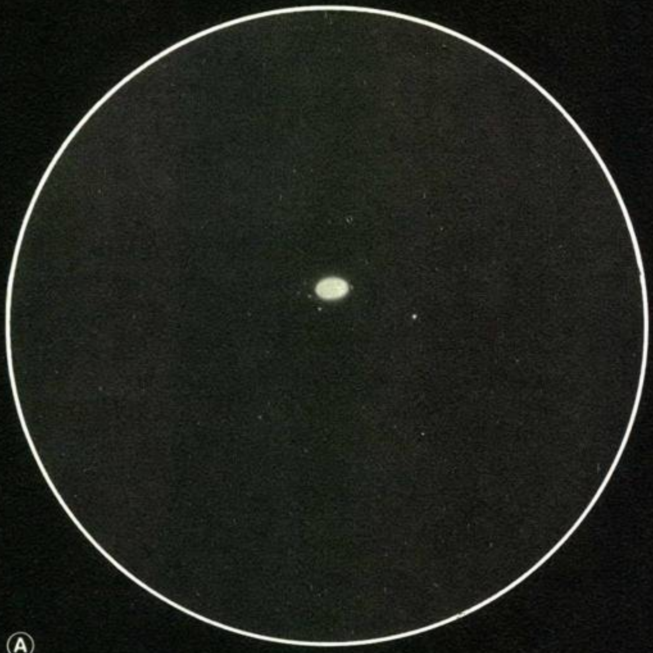
For almost the entire month, Mercury will be visible below and to the right of Venus in the early evening sky shortly after sunset. On May 1, the planet is magnitude -1.0 — but its brightness steadily drops by about 0.1 magnitude per day for the en-

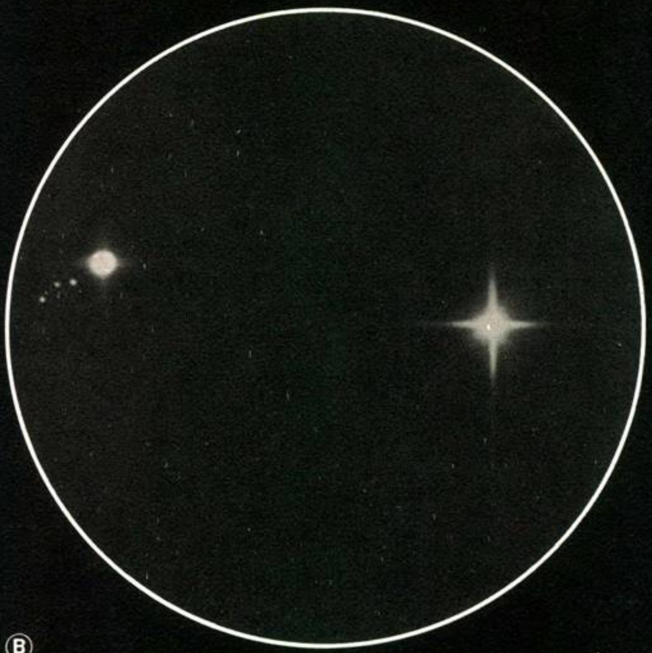
Above: Eros — the celestial speedster — left its unmistakable trail during this 25 minute exposure on Fujichrome R-100 film. At the time the photo was taken (9:15 to 9:40 p.m. PST, Jan. 20), the asteroid was about 20 minutes of arc from Pollux, the brilliant image in this six inch f/4 reflector view.

Photograph by Patrick Michaud

Below: Viewed from Charleston, W.Va., the moon, Venus and Jupiter united in this rare and dramatic grouping on Feb. 13, 1975. The eight second exposure on Ektachrome-X film was taken at f/2.8 with a Nikkormat camera equipped with a 50mm f/1.4 lens. This celestial grouping was visible the world over.

Photograph by Chris Callahan





Ⓐ

Six of Saturn's satellites are easily captured in this prime focus 40 second exposure on GAF 500 film through a 14 inch Celestron telescope. Titan is the brightest object to the right, while much fainter (11th magnitude) Iapetus is about the same distance above and left of the overexposed image of Saturn. The four moons clustered to the left (west) of Saturn are — from top to bottom — Rhea, Enceladus, Dione and Tethys. The remaining objects are background stars. Photo was taken March 1, 1975 at 1:15 a.m. EDT.

Photograph by Leo C. Henzl Jr.

Ⓑ

Jupiter — with its moons nestled nearby — offers a striking contrast with dazzling Venus in this six inch Cave telescope view. A five second exposure on GAF 500 film captured this rare conjunction on Feb. 17, 1975. The SLR camera was located at the instrument's Newtonian prime focus.

Photograph by Byron L. Labadie

tire month. The innermost planet will be at its maximum apparent distance from the sun on the 16th with the prime observing period ranging from the 7th to the 21st of May. Compare Mercury to Aldebaran when the two seem closest around the 10th.

Telescopically the little planet rapidly passes from an 80 percent gibbous phase, 5.7 seconds of arc in diameter on the 1st to a 9 percent crescent, 11.1 seconds in diameter by month's end. Complete observing details were given in last month's Gazer's Gazette.

Saturn

The beginning of May marks the end of good Saturn observing for 1975. But nontelescope users are in for a treat as both Venus and Saturn share the constellation Gemini for most of the month. Venus passes three degrees north of Saturn on the 23rd and the moon is near both planets on the 14th. Saturn at magnitude +0.4 still outshines Castor and Pollux in Gemini.

Telescope users will see Saturn and its rings shrink in width from 38.6 to 36.2 seconds of arc in May as the planet increases its distance from Earth from 877 to 914 million miles during the month.

Jupiter

The giant planet can be easily seen low in the east for up to an hour before sunrise. At magnitude -1.7 it is unmistakable. Since Jupiter is near its maximum distance from Earth and appears close to the horizon, telescopic observation should be delayed until later this year.

Mars

Although the red planet is higher in the morning sky than Jupiter, it is much fainter at magnitude +1.0 and thus harder to locate. Both Jupiter and Mars are in Pisces during most of May, so confusion with bright stars is ruled out. The two planets are the only bright celestial objects in the morning sky apart from the moon. Telescopically, Mars is only six seconds of arc in diameter and of little interest at this time.

Eta Aquarid Meteors

Once again the moon is in the wrong place during a meteor shower. This shower, one of the best half dozen of the year, can provide up to 20 meteors per hour in clear, dark skies. Unfortunately that rate applies only after 2:00 a.m. on May 6, which is not long before moonrise — so meteor observers are foiled again. Normally these very fast and bright meteors would be seen in the eastern sky.

Astronomy:
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G. D. Roth
Munich, Germany

Translated from the German
by A. Beer

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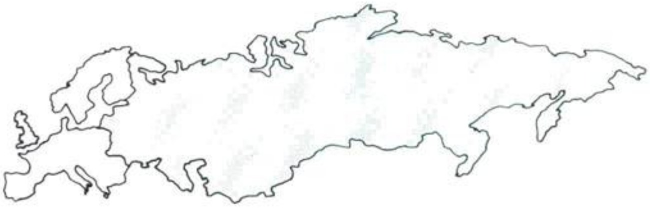

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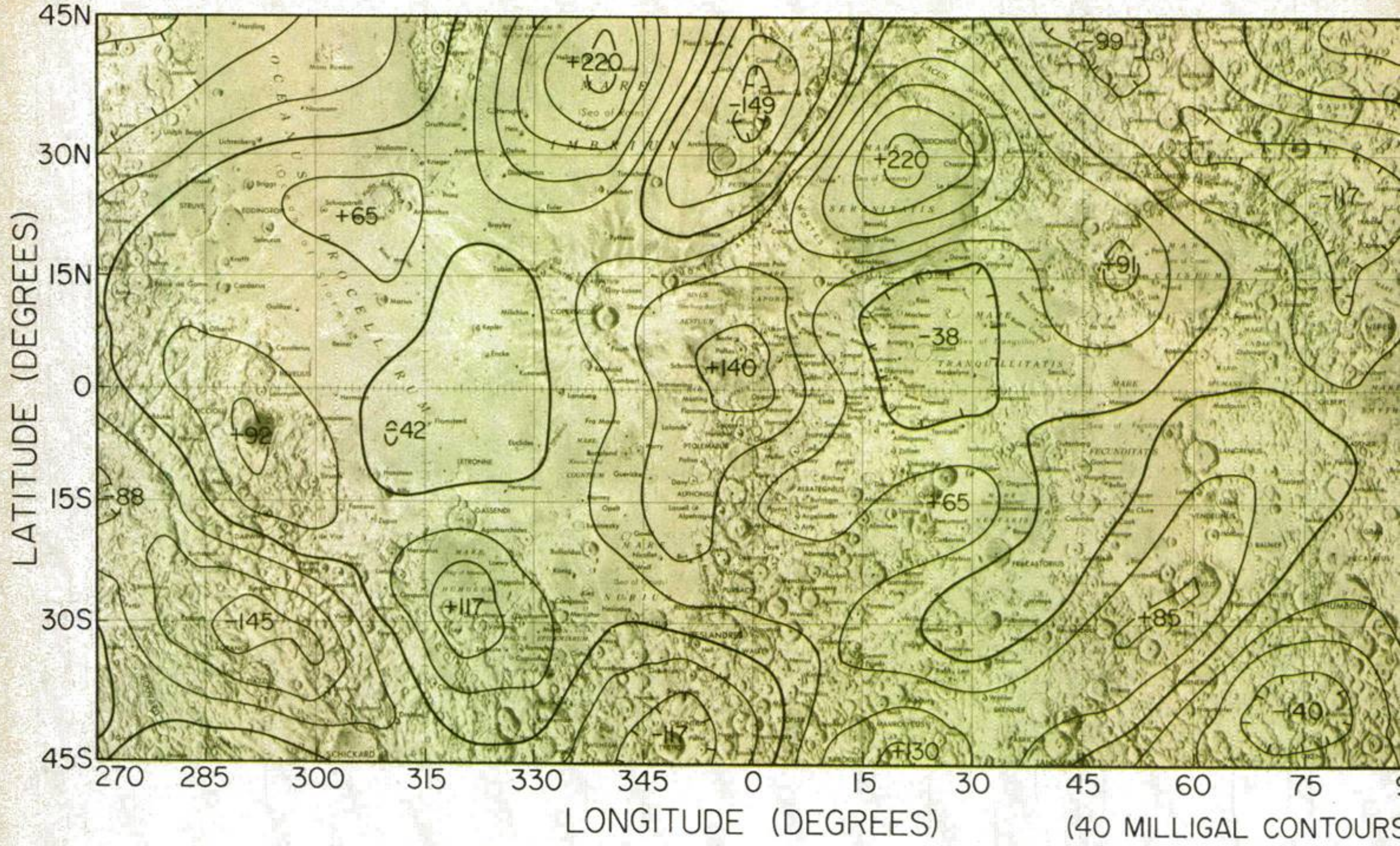
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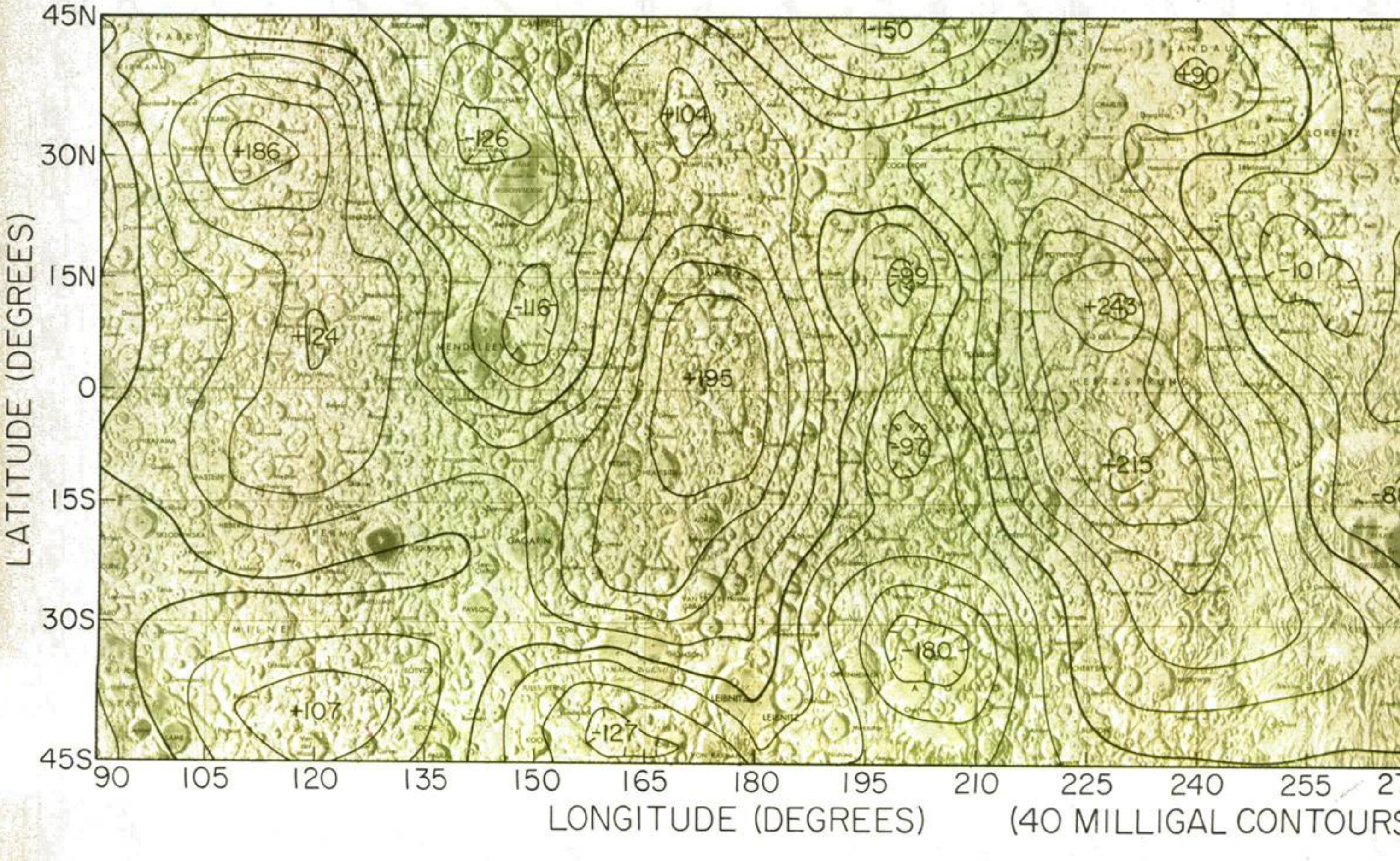
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Gravity Map Shows Volcanically Lopsided Moon

by
Raymond Villard

A newly refined map of the moon's gravitational field by Caltech planetary scientist Alfred Ferrari and geologist Eugene Shoemaker suggests that volcanic activity once occurred much more extensively on the lunar nearside (side always facing Earth) than the farside. The researchers base their conclusion primarily on the discovery that regions of concentrated mass (called *mascons*) are only distributed on the moon's nearside. Models for a moon with internal lava flows predict such a lopsided effect.

In the late 1960s scientists first learned that the moon had a "lumpy" gravitational field. Spacecraft flying over large lava filled basins unexpectedly accelerated, indicating the presence of an unusually strong gravitational field. Apparently these dark circular seas, or ringed *mare* were sites of mascons — but how did they get there?

If the moon has always been a geologically cold, dead world, then mascons could be carcasses of large impacted meteors. A cold moon would be rigid enough to prevent the heavy masses from sinking to the center. Lava filling the basins would have only been material temporarily melted by impact heat. But if the moon once had a very warm, molten interior, large lava flows might have filled lowland areas with sufficient amounts of material for creating mascons. Apollo samples confirm that mare material itself is roughly 1.2 times denser than rocks from the lunar highlands.

A new detailed map by Caltech scientists charts, for the first time, the total gravitation field of the moon. Contour lines identify regions of relatively high and low gravitational strength much as contour lines on a relief map highlight varying altitudes. Markings indicating high gravitation overlap large, flat ringed basins on the lunar frontside. In contrast, regions of greater gravitational strength correspond to rugged highlands on the lunar farside. This article details the significance of these gravity distributions.

The new gravitational map shows that mascons exist only on the moon's frontside. In contrast, the lunar farside is characterized by a broad, strong gravitational field overlapping the highland areas. The farside field is interspersed with locations of relatively low gravitational intensity corresponding to ringed basins.

The map's researchers believe that large molten lava flows best explain this puzzling imbalance. More lava would have spilled into the lunar frontside since it consists of many large lowland areas, instead of the highland regions predominating on the farside. The new farside basins were only partially or never flooded by lava.

Ferrari emphasizes that the new map "represents the first believable gravitational plotting of the farside." The researchers were the first to use data from tiny subsatellites deposited in lunar orbit by Apollos 15 and 16. Unlike previous studies, they watched low altitude perturbations in the satellites' orbits over long periods of time — averaging one orbit per day for one year. Mascons decayed the orbit of one subsatellite so badly that it crashed into the moon after 34 days.

Earlier maps relied on data from a series of Lunar Orbiter spacecraft which photo-mapped the moon shortly before the manned Apollo missions. Because the probes followed highly elliptical and shifting orbits, scientists could not get a very accurate idea of the farside gravitational field — nor were the orbiters tracked as frequently or closely as the Apollo subsatellites.

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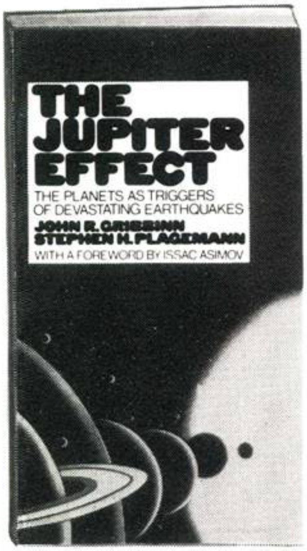
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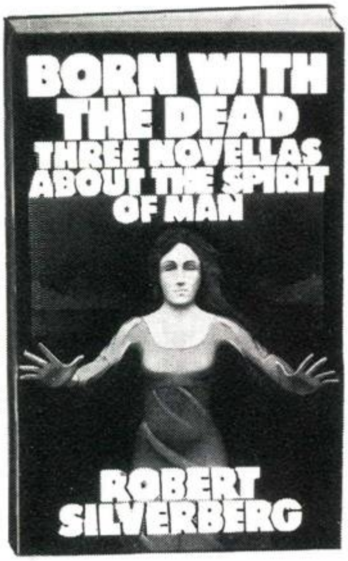
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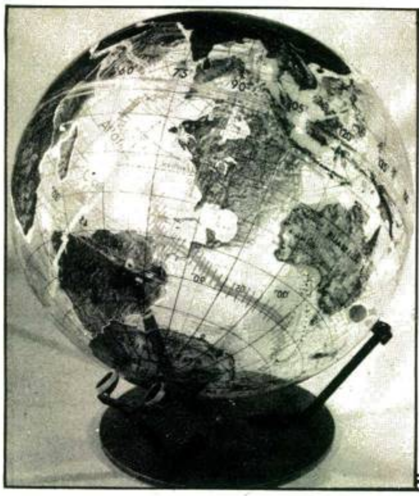

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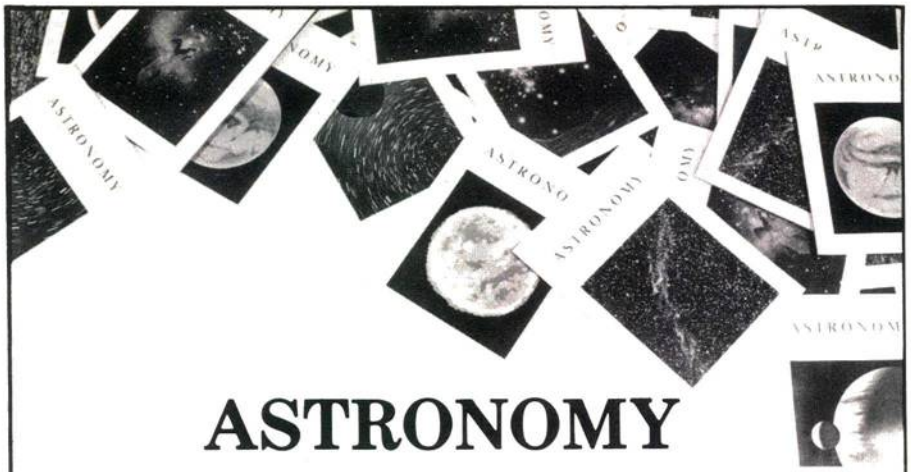

ASTRONOMY

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Vol. 2, No. 4 - April 1974	Available	Vol. 3, No. 4 - April 1975	Available
Vol. 2, No. 5 - May 1974	Short supply	Vol. 3, No. 5 - May 1975	Available
Vol. 2, No. 6 - June 1974	Available	Vol. 3, No. 6 - June 1975	* NYP
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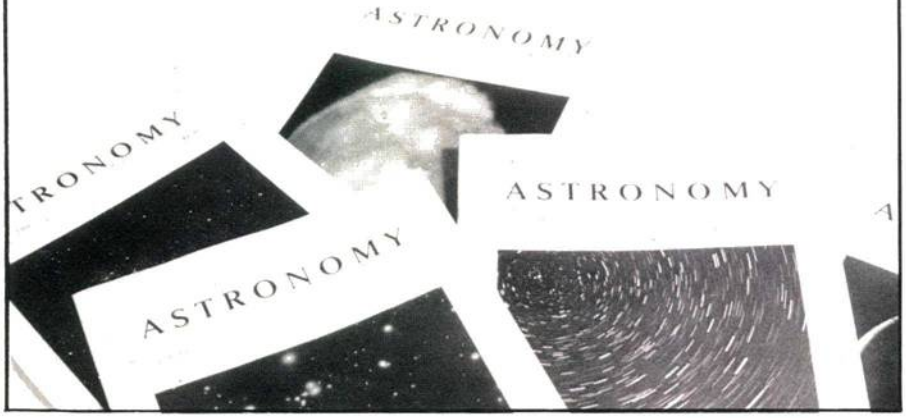

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INFORMATION WANTED — On Herschel type of off-axis telescopes and degrees of aberrations caused in 8" scopes of this type. Write John M. Grooms, Rt. 4, Box 254, Goshen, IN 46526.

INFORMATION WANTED — On Bermuda Triangle, UFOs, psychic phenomena, etc. Write David Lewis, 2519 Applelane Dr., Kalamazoo, MI 49008.

INFORMATION WANTED — On astronomy groups in Cleveland area. Write Ken MacDonald, 13946 Oak Brook Dr., North Royalton, OH 44133.

INFORMATION WANTED — Or plans for building observatory with dome or flat roof for an 8" reflector. Write Hal Miller, 22633 Pontchartrain Dr., Southfield, MI 48076.

ANNOUNCEMENT — The 3rd annual Southern California "Amateur Astronomers' Swap Meet and Optical Fair" will be held on April 27 at the Garvey Ranch Park, 781 S. Orange St., Monterey Park. For futher details, contact James W. Smith, 267 E. Glenarm St., Pasadena, CA 91106. Phone (213) 682-1674.

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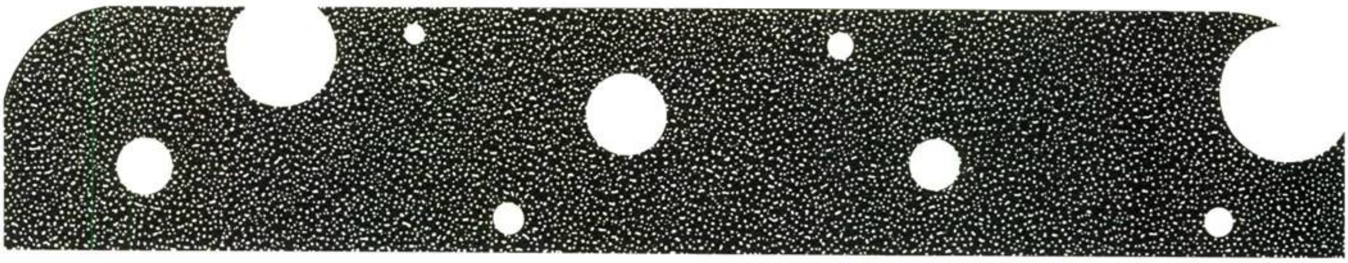


Retesting Relativity

by
Gerrit L. Verschuur

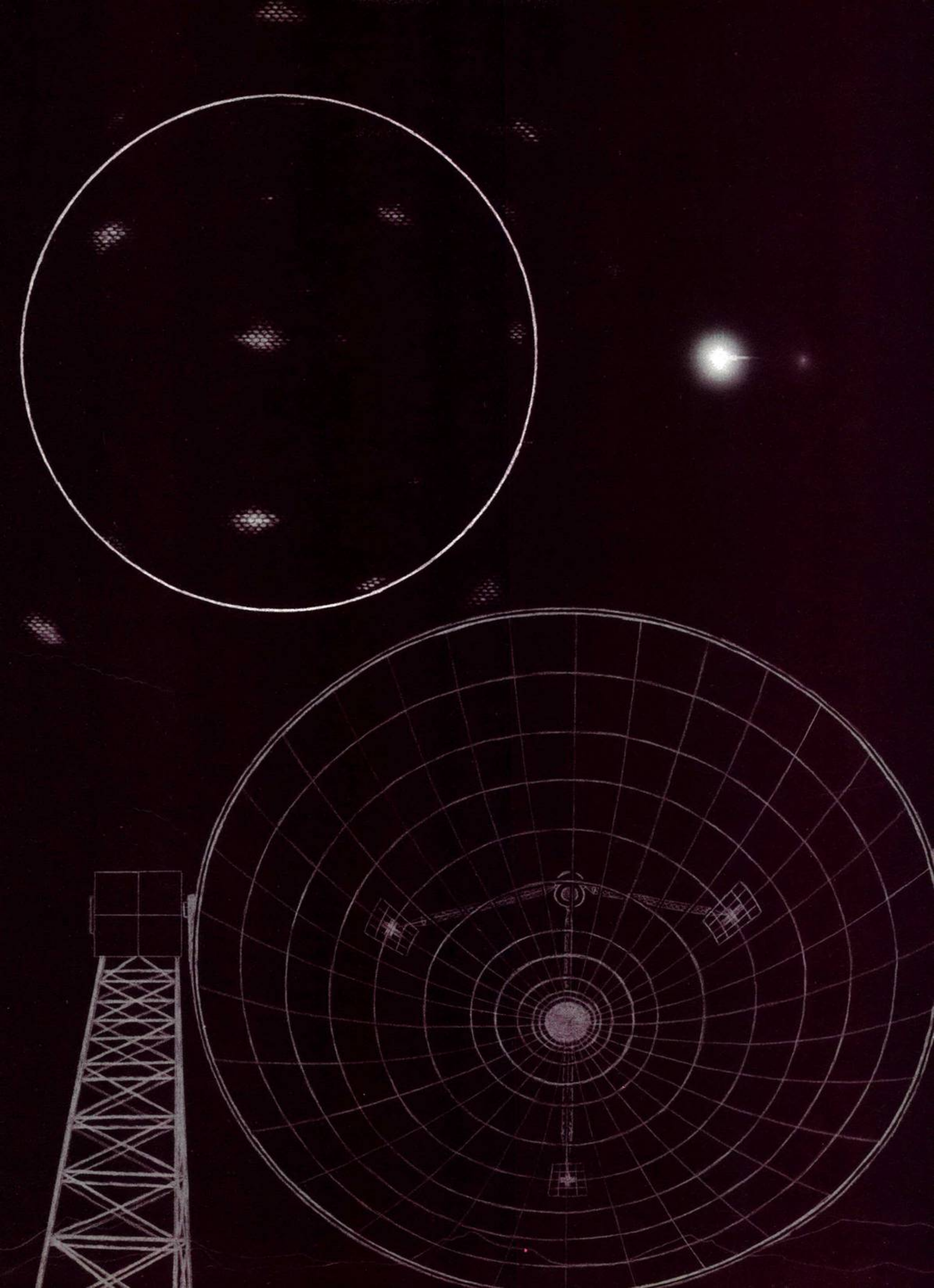
Some experiments in physics can only be performed in the largest laboratory that exists — the universe. The tools of the experimenter then become the planets, stars and even galaxies. Such a cosmic laboratory is needed to test the theories that tell us what gravity is.

Despite being the weakest force in nature, gravity is a persistent (and sometimes painfully obvious) influence in our daily experiences. And although we utilize gravity in some special way every moment, it remains an enigmatic force in the universe. Ever since Galileo supposedly first started dropping things off the "Leaning Tower of Pisa", mankind has sought to learn more about gravity.

Three centuries ago Isaac Newton formulated the basic laws of gravity that describe how objects

During a crucial experiment, a radio telescope notes a distinct change in the apparent position of a quasar shortly before the sun occults it (the sun is seen in its radio image). Of course the quasar has not really moved in space. Instead, the sun's powerful gravitational field slightly bends light rays passing near it making the quasar seem nearer the sun that it actually is. The ghost image is the quasar's true position. Einstein first predicted this phenomenon in his general theory of relativity. Today new tools and techniques allow astronomers to continue retesting Einstein's theory and try out a few modified theories of their own.

Artwork by Adolf Schaller



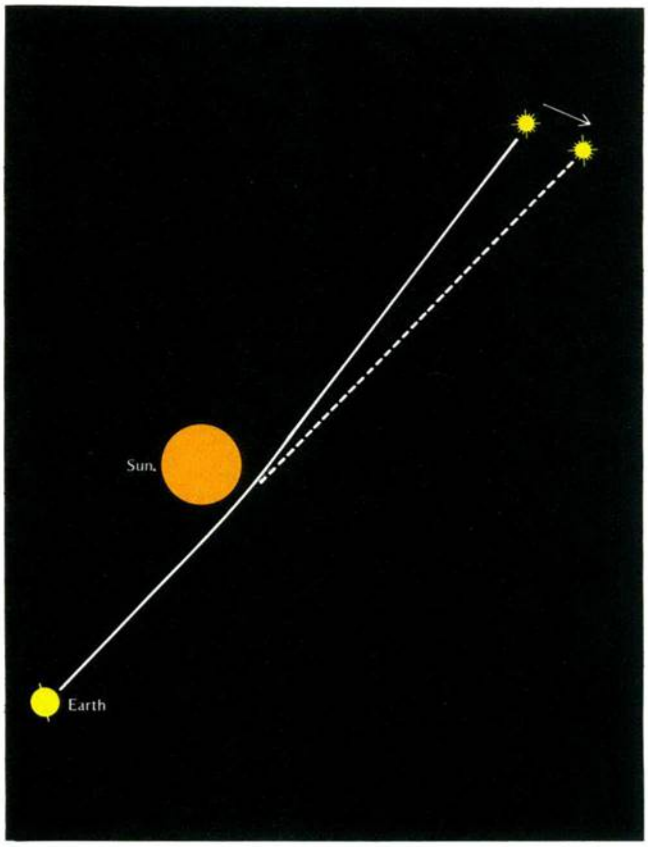
behave within a gravitational field. Newton's laws remained unchallenged until the beginning of this century when Albert Einstein revealed that, while they remained true in most cases, the laws did not account for the effects of strong gravitational fields on light and time. Einstein developed a new, refined explanation of gravity in his *theory of relativity.* Today astrophysicists apply relativity to everything from predicting black holes to describing the structure and behavior of the entire universe. Meanwhile, experts continue reworking and retesting Einstein's critically important *theory of gravitation.*

According to Einstein, light bends when it passes close to a large object such as a star. The only way to test this part of the theory is to watch what happens when light actually does pass a star — such as during a total solar eclipse. When the moon blots out the sun, it is possible to detect stars very close to the sun's position. If the light from a star has been bent while passing the sun, then the star's apparent location will be different from an observation made when the sun was not in that part of the sky.

Although such experiments were performed earlier this century, the results have never been totally satisfactory since the corona (the solar atmosphere) makes accurate measurements very tricky. The experiments confirm that light bends in passing close to the sun, but they do not show whether Einstein was right or if, instead, some more recent theories correctly describe gravity.

Since Einstein's work there have been many attempts to find a better theory explaining the effects of gravity. The differences between more recent theories and Einstein's are insignificant when we consider our perception of the everyday world. But for a physicist trying to understand exactly what makes the universe tick, the differences are substantial. Experiments for measuring to an accuracy that permits detection of these small differences require the cosmos as the laboratory.

One of the proponents of a revised theory of relativity is Robert Dicke of Princeton University. One way to compare his theory with Einstein's involves carefully observing the way Mercury orbits the sun. Einstein predicted that the perihelion of Mercury's orbit (the point at which the planet is nearest the sun) should itself move around the sun if his theory of relativity is correct. Since Mercury's orbit is so elliptical, astronomers can measure the location of the perihelion point very accurately. It shifts 43 seconds of arc per century — not large by any standard since it would take three million years for the perihelion shift to trace one complete swing around the sun. Einstein's theory predicts this amount of change. However, Dicke's theory calls for a smaller shift. He explains Mercury's 43 second shift per century as being a combination of his (Brans-Dicke) theory and the effect of an oblate sun. This means that if the sun is not a perfect sphere, it would affect the orbit of Mercury in a way that would erroneously lead observers to believe that Einstein was correct.



Light from a star normally travels in a straight line. When the light grazes that limb of the sun, its gravity deflects the beam. The diagram here and the illustration on page 44 are greatly exaggerated. In reality, extremely precise observations are required to measure this change in the star's apparent position.

By measuring the shape of the sun, astronomers can establish if it deviates from a perfect sphere and allow for that in Einstein's theory. However, the precision required for such a measurement is very difficult to achieve. Dicke spun a disk in front of the sun and recorded the changes in light that leaked over the edge of the disk. He concluded that the sun was not a perfect sphere and that his refinement of gravitational theory was correct.

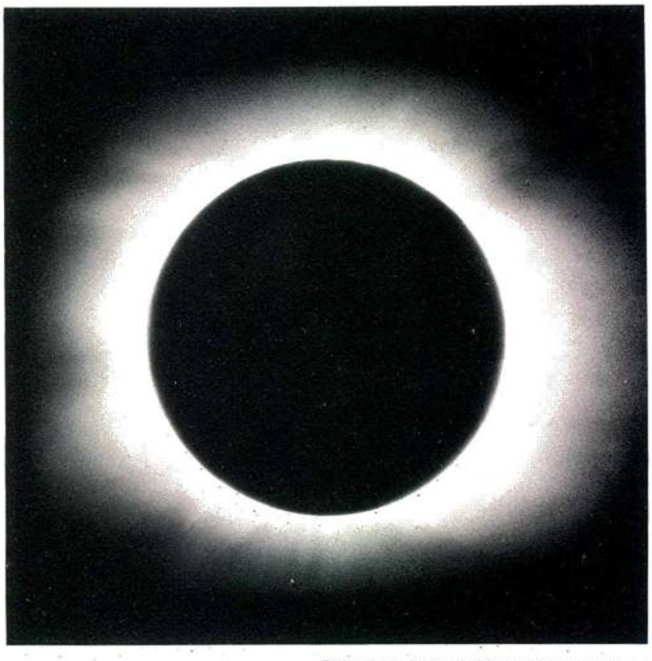
Since then, other experimenters have discovered that the brightness of the sun varies over its disk due to the presence of bright spots called *faculae.* These would have led to a misleading result in Dicke's experiments. In any case, the motion of Mercury's perihelion point can be explained by both theories.

The Brans-Dicke theory predicts a slight difference in the way light bends when passing the sun as compared with Einstein's original work. The difference is so small that present day optical measurements on stars are not accurate enough to settle who is right. Instead, observers have to rely on radio measurements.

Radio signals from distant radio sources such as quasars also bend when they pass by the sun. Rather than waiting for a total solar eclipse, measurements can be made any time that the sun moves in front of a suitable radio source. A good candidate is the strong radio-emitting quasar, 3C279, which the sun occults every October. By using a *radio interferometer* — a combination of several radio telescopes which can accurately observe small sources — the quasar's apparent position is measured as the sun moves in front of the source. If the radio signals are bent by gravity, the source will appear to move as the sun approaches the quasar's position.

However, radio signals can also be bent when they pass through clouds of electrons — which is what the solar corona consists of. This bending (called *refraction*)has nothing to do with gravity. (Refraction also occurs to light when it passes through our atmosphere.) Refraction in the corona is much larger than the bending caused by gravitation, but radio astronomers have developed a way of differentiating between the two types of bending. The amount of refraction in the corona varies at different wavelengths while the gravitational bending remains the same regardless of wavelength. By making the measurements at two radio wavelengths simultaneously, astronomers sort out one effect from the other.

Recent measurements of this bending in radio signals from quasar 3C279 and several others reveal that their apparent changes in sky position is perfectly consistent with Einstein's theories. No modification, such as proposed by Dicke and others, is needed. These experiments required years to perfect and a definitive result was only obtained some months ago.



Photograph by Jeffrey Baumgardner

Einstein staked his general theory of relativity on the test that starlight should be deflected by the sun's gravitational field. The coincidental match between the angular diameter of the sun and moon that creates a solar eclipse allowed scientists to test relativity — as early as 1919 — by observing the behavior of starlight near the sun's limb. Results from these and subsequent experiments closely agree with Einstein's predictions.

Several spacecraft have also been involved in confirming Einstein. Signals from the Mars-orbiting spacecraft, Mariner 9, were carefully measured and their bending due to Mars' gravity was determined. Results agree with solar measurements on the bending of radio signals and again confirm Einstein.

The small slowing down of a light (or radio) signal as it goes past a massive body such as the sun can be measured in another way. It requires accurately determining the orbit of, say, Venus by bouncing radar signals off the planet along various points in its orbit. Astronomers would next predict what the time delay would normally be for a radar echo when Venus is at a point in its orbit on the far side of the sun, and compare that prediction to the actual delay time. The sun's gravity should slow down the sun-grazing signal, making it infinitesimally longer than expected. The newly resurfaced 1,000 foot diameter radio telescope in Arecibo, Puerto Rico now makes this experiment feasible.

Several other tests for gravitational theories are now being attempted. The recent discovery of a binary pulsar allows measurements which will likely confirm Einstein's theory to much greater accuracy. The two objects comprising the binary pulsar — probably two neutron stars — are moving about one another in elliptical orbits, and these orbits also rotate in space. They show what is called a *periastron shift* (the equivalent of a perihelion shift) which has already been measured. These observations do not confirm the theory of relativity — yet. However, data gathered over the next 10 years should allow another exciting prediction of relativity to be tested — gravity waves.

Gravity waves — those elusive creatures that have not yet been detected on Earth — are predicted to radiate from an object whose gravitational structure changes suddenly (for example, the collapse of a star into a neutron star or a black hole). If two objects are orbiting each other at the incredible rate that the binary pulsar seems to be, it is expected that radiation in the form of gravity waves should continuously radiate from the system. Although we have no way of measuring such gravity waves directly, the effect of their radiation can be detected because the binary pulsar would speed up in its orbit from year to year depending on how much energy was being released in the form of the gravity waves. In 10 years, this quantity should be known and one of relativity's most important predictions should be confirmed (or disproved).

There is as yet no evidence that makes it necessary to question or modify Einstein's basic work. The tests so far have all confirmed his predictions. His relativity theory, coupled with new instruments and observational techniques, continues as the cutting edge of our knowledge about the universe.

PUBLISHER'S MEMO

ASTRONOMY'S December survey is finally tabulated, and you will find some of the more interesting tabulations below.

First, I'd like to thank you all for your cooperation. Since we only expected a 5 to 10 percent return based on what other magazines experience with similar surveys, your 30 percent response is indeed gratifying and tells us that you are deeply involved with ASTRONOMY.

1. Mostly Male:
   92.5%
2. Mean age: 30
   Ages 18-35:
   51.0%
3. Novice or intermediate astronomy enthusiasts:
   78.3%
4. ASTRONOMY is Better or Much Better than promised or expected:
   75.5%
5. Do not think ASTRONOMY's cover should be changed:
   86.9%
6. Readers rate ASTRONOMY's articles and departments Good to Excellent:
   82.5%
7. In general, readers Always or Usually read most articles and departments in ASTRONOMY:
   79.7%
8. Readers say ASTRONOMY Usually or Always gives ade- in-depth coverage to its articles and departments:
   88.2%
9. The majority of readers find ASTRONOMY understandable:
   90.8%
10. Readers would like to see articles on the following topics in the future (listed in order of highest reader preference):
    A: Black Holes
    B. Intelligent Life Beyond Earth
    C. Galaxies/Origin of the Universe
    D. Pulsars/Interstellar Exploration/Quasars
    E. Planetary Exploration/the Space Shuttle and Future of Manned Space Program/Planets/the Birth and Death of Stars

(You will note ASTRONOMY has covered about eight of the subject areas in the last five issues — including this issue.)

12. Own telescopic equipment:
    91.2%
13. Only own binoculars:
    20 3%
14. Average value of telescopic equipment:
    $325.22
15. Built some of their telescopic equipment themselves:
    32.7%
16. Plan to buy a prebuilt telescope in the next 12 months:
    24.6%
17. Plan to build a telescope in the next 12 months:
    15.0%
    average value: $216.27
18. Plan to buy telescope accessories in the next 12 months:
    54.2%
    average purchase: $106.22
19. Regarding articles for Equipment Atlas:
    66.7% Want articles on how to use prebuilt telescopes and accessories which incorporate theory on how optical systems and equipment work.
    25.0% Want articles on how to build telescopes and other astronomy equipment themselves.
    8.3% Want reports on telescopes and equipment other astronomy enthusiasts have built.

(Keep your eye peeled for "something special" in future installments of Equipment Atlas. We think what we have in mind will satisfy everyone interested in telescope building. Also, anyone who has built an unusual telescope or made some novel adaptation of unusual equipment to astronomy, please send us a letter outlining your project. If we think our readers would be interested, we'll get in touch with you — so include your phone number.)

20. Most readers are photography enthusiasts:
    62.1%
21. Photography enthusiasts whose interest is not exclusively astrophotography:
    51.6%
22. Own photographic equipment:
    75.3%
    average value: $385.49
    Own photographic equipment worth $201 or more:
    45.7%
    average value: $577.52
23. Will buy photographic equipment in the next 12 months:
    46.4%
    average purchase: $195.29
    Will buy photographic equipment worth $201 or more in the next 12 months:
    15.4%
    average purchase: $406.86
24. Would be most inclined to purchase major pieces of photographic equipment if they were advertised in ASTRONOMY:
    30.8%
25. Would like to see more advertising in ASTRONOMY:
    25.7%
26. Would be inclined to purchase the following if they were advertised in ASTRONOMY:

Science book clubs	61.1%
Astronomy travel tours	59.7%
Science fiction books and magazines	49.2%

27. Do not subscribe to other astronomy magazines:
    45.9%
28. Would not miss any other magazine on astronomy, if ASTRONOMY magazine were the only one published:
    60.7%
29. Subscribed to ASTRONOMY because of its popular appeal and full color brochure which promised color photographs:
    56.8%
30. Readers Always or Usually en- the following materials used in ASTRONOMY:

Color observatory photos	98.3%
Color photos by amateurs	91.4%
Paintings by Victor Costanzo	90.3%
Paintings by John Clark	89.8%
Paintings by Rick Sternbach	89.4%
B&W observatory photos	86.8%
B&W photos by amateurs	71.2%

31. Readers Always or Usually find the following materials useful:

Color diagrams	71.1%
Planet Finder chart	69.8%
Other maps	59.1%
Star Dome map	58.0%
Constellation Close-Up map	51.2%

(Even before this survey was tabulated, ASTRONOMY changed the design of Star Dome so that it now incorporates a full color map of the month's sky, as well as new maps for the Close-Up section which was added to Star Dome. We hope you have enjoyed these changes and that the changes now make ASTRONOMY's maps useful to more readers — let me know. Incidentally, in response to the many letters we have received from readers, we are once again publishing a Table of Objects in our Close-Up section.)

32. Readers rate the overall quality of ASTRONOMY's color and B & W reproductions and printing Excellent to Good:
    98.9%
33. Would subscribe to ASTRONOMY even if color were reduced or eliminated, or the price and size increased:
    59.3%

(This question was included as a round about way of determining how valuable readers find ASTRONOMY. Even though we plan no major changes for the immediate future, it is gratifying to learn that almost 2/3 of our readership is as loyal as it is.)

34. College and advanced degrees: 41.1%
35. Pass along readership: 1.83 readers per copy
36. Managers and Professionals: 36.5%
    Scientists and Engineers: 13.7%
    Educators: 8.3%
37. Personal annual income $15,000 or more: 33.5%
38. Household annual income $17,000 or more: 55.9%
39. Always or Usually receive ASTRONOMY on time: 94.7%

(We're thinking of resurrecting the Pony Express to adequately handle delivery to the unfortunate 5.3 percent who occasionally, seldom or never receive ASTRONOMY on time.)

Here are a few more interesting ways to look at some of our survey tabulations. Do you know that the total combined ages of ASTRONOMY's readership is about 1.2 million years? Do you know... that the total combined value of ASTRONOMY subscribers' photographic equipment is about $11,330,514.00?... in the next 12 months you will purchase an additional $3.5 million worth of photo equipment? ... you own telescopic equipment worth $11.6 million, and will purchase an additional $8.6 million worth of astronomical equipment, parts, accessories in the next 12 months? You will make our advertisers very happy!

One final mind-boggling statistic before we leave this survey — the total combined annual household income of ASTRONOMY's subscribers is almost $1 billion! To be precise: $838,890,000.

All in all, the knowledge we gained from this survey has immeasurable value. We know you better than we did before and are now better able to anticipate your likes and dislikes. With the readership information we gained we can provide a magazine whose value to you will grow and improve beyond the hallmark of excellence we've achieved to date. We know where our weaknesses lie now, and can turn them into strengths. It is our sincere desire to serve you all fairly — with quality, information, relevance, vitality, dynamic growth.

Each and every month, in each and every way, ASTRONOMY will become better and better. This is our quest — this is my pledge!

With this May issue we are pleased to welcome 6,000 new ASTRONOMY magazine subscribers. Since I like to get letters from our readers, drop me a line from time to time. Whether you have "beefs or blessings", let me hear from you.

'Till next month — Peace!

Sincerely,

Stephen A. Walther

* * *

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GAZER'S GAZETTE

Lunar Eclipse of the Decade

The best lunar eclipse of the 1970s will be visible over all of North America on the night of Saturday, May 24, 1975. The eclipse will be total — the first visible from the United States in over three years.

An eclipse of the moon occurs only at full moon, and only when Earth, the sun and moon are exactly aligned. At such times, the moon becomes engulfed in Earth's shadow; it does not completely black out the moon, but does cut our satellite's brilliance to less than one percent of the normal full moon brightness. The eclipse begins at midnight EDT (for other time zones, see table) when the lower left edge of the moon will dim as it slowly enters Earth's shadow.

The shadow, usually a copper hue, will seem to sweep over the moon during the following hour. An hour later, the total eclipse begins. Midway through the eclipse — nearly two hours after the first dimming is noticed — the moon will appear to be a deep rust color. The events are then seen in reverse order until the moon is completely free of Earth's shadow, 3-1/2 hours after the eclipse began.

Binoculars are a perfectly adequate optical aid for observing a lunar eclipse. If a telescope is used, the lowest power eyepiece should be employed so that the entire disk of our neighbor world remains in view.

What should you look for during a total eclipse of the moon? If you are a photography buff, don't pass up this opportunity to try to get a fine shot to add to your collection (see accompanying boxed article).

If you don't plan to photograph the event, you can simply relax and enjoy the spectacle in comfort. It's a perfect opportunity to get together with other enthusiasts (or even semienthusiasts) and spend three or four hours under the stars. Remember, during the total phase the moon drops to between 1/100 and 1/100,000 its normal brightness — so the stars previously dimmed by moonlight will seemingly emerge to frame the coppery disk. Can you see fifth or sixth magnitude stars at midtotality, where only second or third were seen before? That's also a time to make a magnitude estimate of the moon. Nearsighted people can do this best by removing their glasses and comparing the unfocused moon with the stars. If it is a dark eclipse, the moon will be fainter than nearby Antares (the moon will be near Beta Scorpii during the eclipse) and possibly as faint as some of the surrounding second and third magnitude stars.

During the 10 minutes centered on midtotality, you should make a visual estimate of the darkness of the eclipse. A scale which was set up some years ago by French astronomer A. Danjon is a standard for such estimates. Simply make note in which one of these categories the eclipse seems to fall. The scale is intended for unaided eye estimates.

L=0: Very dark eclipse; moon practically invisible, especially in midtotality.

L=1: Dark gray or brownish eclipse; lunar details distinguishable only with difficulty.

L=2: Deep red or rust colored eclipse with the central part of the shadow very dark and the outer edge of the umbra relatively bright.

The moon was not completely immersed in Earth's shadow when this eight second exposure on High Speed Ektachrome was shot during the Feb. 10, 1971 lunar eclipse. The white edge is the portion outside the main shadow area. Once entirely inside the shadow, the moon usually glows with an eerie copper hue (like the cover photo). The total phase of the eclipse can last almost two hours. The eclipse this month is a long one, with 90 minutes of totality — the longest since 1964. This photo was taken through an eight inch Celestron telescope.

Photograph by John Sanford

L =3: Brick-red eclipse, usually with a bright gray or yellow rim to Earth's shadow.

L =4: Very bright copper-red or orange eclipse, with a bluish, very bright edge to Earth's shadow.

According to Danjon, this eclipse should be only moderately dark — possibly L = 3. Danjon has found that eclipses of the moon are darkest in the two years following minimum sunspot activity. Minimum solar activity was due this year. However, M. Waldmeier of the Swiss Federal Observatory (a major sunspot record center) reports that minimum solar activity will not occur until 1976. There is, as yet, no satisfactory explanation for why sunspot activity should affect lunar eclipses (if, in fact, it does), but statistical evidence points to this conclusion.

Weather at the time of an eclipse has a major effect on the color and intensity of Earth's shadow. Clouds, dust and atmospheric pollution around the circumference of Earth block more light than clear skies. Eclipses recorded in 1883, 1903, 1913 and 1963 were extremely dark because of widespread dust created by massive volcanic eruptions. The more light that our atmosphere absorbs, the darker the eclipse.

The eclipse will have a dramatic effect on the moon itself. The sudden plunge into darkness will cause an abrupt temperature change of almost 300 degrees. The surface temperature will drop from +230 degrees to -50 degrees Fahrenheit. A Surveyor spacecraft was in the shadow during an eclipse in 1967; it functioned well and photographed an eclipse of the sun from the moon. No astronauts, however, have been on the moon during an eclipse.

The detailed explanation for the lunar eclipse phenomenon has been known for at least a century. Here is a small section from a magazine article on eclipses by Simon Newcomb written at the turn of the last century:

"When the eclipse is total, the light which almost always illuminates the eclipsed moon will be very plainly seen, because it is not drowned out by the dazzling light of the uneclipsed portion. This light, of a dull red color, arises from the refraction of Earth's atmosphere....Those rays of the sun which just graze Earth, or pass within a short diatance of its surface are thrown by refraction into the shadow, where they fall on the moon. The red color is due to the same cause that makes the sun appear red at sunset, namely, the absorption of the green and blue rays by the atmosphere which lets the red rays pass."

Newcomb was the most prominent astronomer in the country around 1900 and was widely read. In this article (later reprinted in **Astronomy for Everybody**, now long out of print), Newcomb makes a surprisingly accurate speculation on the appearance of Earth during such an eclipse.

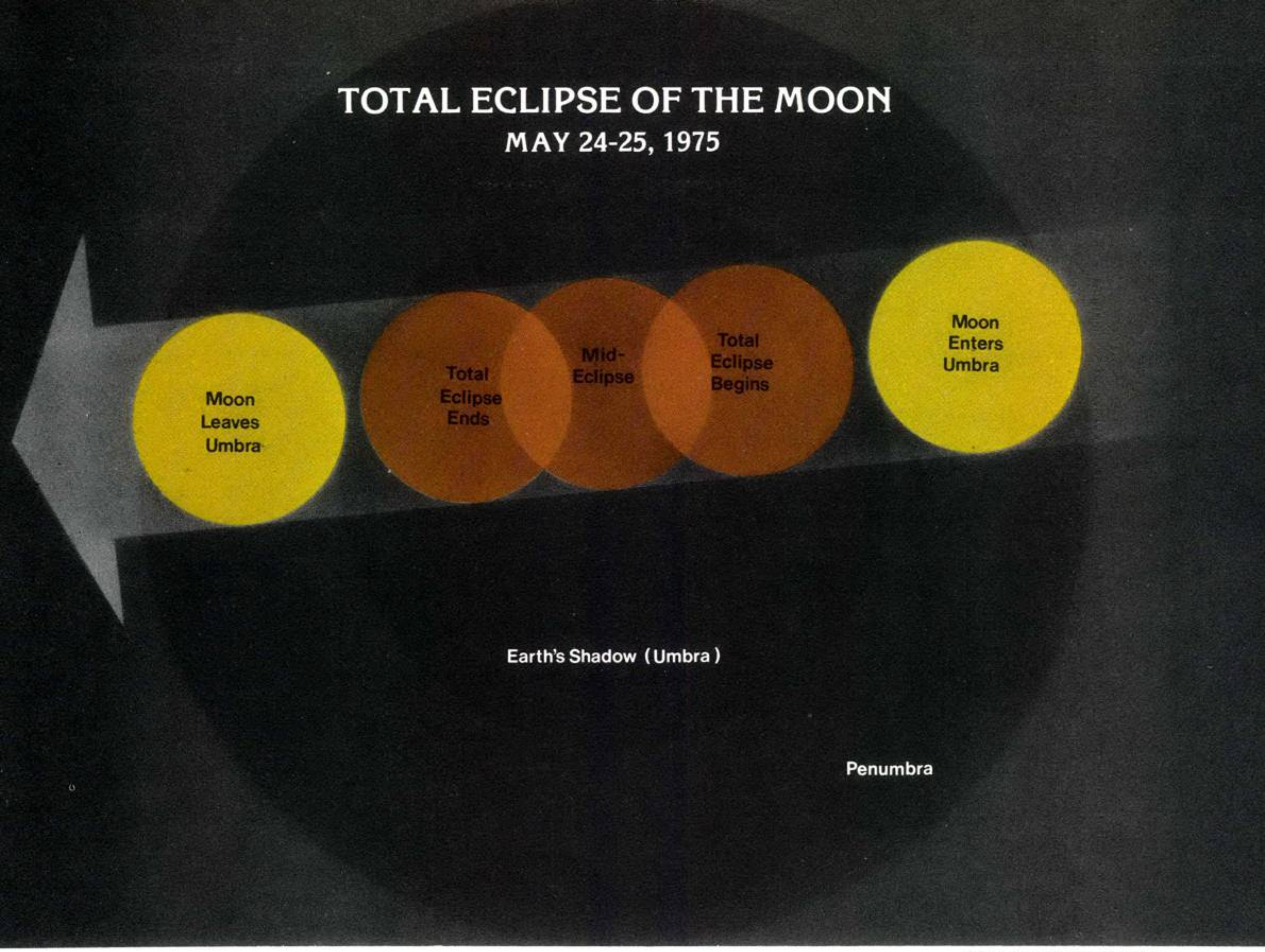
"When the moon is eclipsed an observer on that body would see an eclipse of the sun by Earth. The cause of the phenomenon we have described would then be plain enough to him. The apparent size of Earth would be much larger than that of the moon as we see it. Its diameter would be between three and four times that of the sun. At first this immense body would be invisible when it approached the sun. What the observer would see would be the cutting off of the light of the sun by the advancing but invisible Earth. When the latter had nearly covered the sun, its whole outline would be shown to him by a red light surrounding it, caused by the refraction of Earth's atmosphere. Finally, when the last trace of true sunlight had disappeared, nothing would be visible but this ring of bright red light having inside of it the black but otherwise invisible part of Earth."

Newcomb was fully aware of all the circumstances involved and therefore did not feel hesitant to make such a statement. (By contrast, he was also predicting around the same time that heavier-than-air vehicles could never fly for long distances. He should have stuck to astronomy!)

You don't have to wait until mideclipse to be watching for unaided eye phenomena. Earth's outer shadow region (called the penumbra — where an observer on the moon would see a partial eclipse) is a virtually transparent diffusion region around the main, umbral shadow. Yet the penumbra can be detected as a faint gray haze a few minutes before first contact with the umbra. Watch the lower left edge of the moon and make note of the time you first notice the penumbra's darkening. This observation plus the "L" value from the table given earlier can

Lunar Eclipse Timetable

Event	Time Zone			
	EDT	CDT	MDT	PDT
Moon enters umbra	12:01 a.m.	11:01 p.m.	10:01 p.m.	9:01 p.m.
Total eclipse begins	1:04 a.m.	12:04 a.m.	11:04 p.m.	10:04 p.m.
Mideclipse	1:49 a.m.	12:49 a.m.	11:49 p.m.	10:49 p.m.
Total eclipse ends	2:33 a.m.	1:33 a.m.	12:33 a.m.	11:33 p.m.
Moon leaves umbra	3:37 a.m.	2:37 a.m.	1:37 a.m.	12:37 a.m.



Artwork by Victor Costanzo

An eclipse of the moon occurs when our satellite passes through Earth's shadow. On May 24, 1975 the moon will be 235,000 miles away — slightly closer than average. At that distance the shadow is 5,800 miles wide. Moving at 2,300 m.p.h., the moon is in the shadow more than two hours. Unlike an eclipse of the sun which is visible only where the moon's shadow strikes Earth, an eclipsed moon is visible over the entire night side of our planet.

be noted on a postcard and sent to The Editors at the address given on page 5. State what optical aid (if any) was used for the penumbra shadow observation.

Other projects — such as precise timings of the four umbral shadow contacts or recording the times various craters are covered by the main shadow — make interesting endeavors for comparison by observing groups on subsequent cloudy evenings.

There are other questions you may want to ask yourself during the total portion of the eclipse. Which craters and "seas" remain visible during the eclipse? Which lunar feature is most conspicuous? Does the edge of the moon become "lost" and merge into the sky background at any point? If the eclipse is rather bright, there will be marked gradations between the intensity of the center of Earth's shadow and its edge. What colors are these various gradations?

Through binoculars or a telescope, prominent bright spots can be distinguished on the moon's surface at the height of the eclipse. These are "young" craters formed during the last 500 million years. The relatively recently exposed soil in these craters has not been darkened by eons of solar radiation. These lighter colored oases will probably stand out in the dim light of the filtered sun.

During this eclipse, the moon will be passing closer to the center of Earth's shadow than in any eclipse since 1964. The next eclipse that passes as deep into the umbral region will not be until July 6, 1982. The next total lunar eclipse visible from North America will occur this year on Nov. 18, but none of the conditions — weather, depth of totality or zone of visibility — will be as good as for this month's event.

Over 2,000 years ago, Earth's circular shadow was taken by the Greeks as evidence that our planet is spherical. Today, astronomers generally regard lunar eclipses as minor scientific phenomena. But through the ages, the lunar eclipse has remained a dramatic, visual spectacle of nature.

Photographing the Lunar Eclipse

by

Leo C. Henzl Jr.

The full moon is almost universally hated by astrophotographers. But when it passes through Earth's shadow, as will occur this month, it's easy to forgive its transgressions in other months. A total lunar eclipse is an opportunity for pictures bound to become real prizes in your collection.

The subject fairly begs to be shot in color. Black and white sequence photos of the entire event may be interesting and informative, but it is the coppery glow of the total stage that gives the event its truly memorable aspect. At totality the eclipsed moon is usually dim indeed, so a high speed color slide film — ASA 100 or faster — is definitely in order. The exposure recommendations that follow are for ASA 100 film; for films of other speeds, alter your exposures accordingly.

What you can do in the way of shooting the lunar eclipse will depend on the equipment at your disposal. Despite its relatively huge appearance near the horizon, the moon is quite a small object — only 0.5 degrees in angular diameter. Its size at your film plane will be just .0087mm per millimeter of camera lens focal length. Thus, with a 50mm "normal" lens, its image is less than 0.5mm in diameter — much too small for a pleasing photo. If you're limited to shooting with this kind of a setup, consider doing an exposure sequence on a single frame if your camera has multiple exposure provisions. If not, as an alternative, set your lens at f/16 and lock your camera shutter open for the entire duration of the umbral phase; the result will be an interesting trail of varied color and width across the film. In either event, orient your camera carefully so that the entire event remains on your film — bearing in mind that the moon will move nearly 15 degrees westward every hour. (See the formulas for determining field coverage in this month's Photography in Astronomy.)

The shortest focal length lens that will provide a large enough image of the moon in isolation is about 300mm — yielding an image diameter of about 2.6mm. This sounds rather small, but at typical slide projection distances the image will be about 3-1/2 inches across. From here on, the longer the lens or telescope, the better in general — up to about 2,000mm.

If you photograph the eclipse from beginning to end, you will be starting and finishing with a photo of an undimmed full moon. Assuming ASA 100 film and a telescope or lens of f/8.0 focal ratio is being used, the correct exposure will be on the order of 1/250 second. If you're using a different f-ratio or film speed, consult the film data sheet and use the exposure recommendation for a front lit terrestrial subject in sunlight, as the full moon is essentially the same thing. Do not attempt to determine exposure with your camera's built-in light meter unless the focal length of your lens is long enough for the moon to fill your entire metering area.

In the initial stages, as the moon moves into Earth's penumbra, it will dim only slightly — not enough for additional exposure. Little transpires during the penumbral phase; save your film for the more interesting events to follow. In fact, for a reasonably realistic appearing record of the event, use the same 1/250 second exposure at f/8.0 until the moon is about 75 percent into the actual umbral phase. At this juncture — assuming that you are exposing a frame every few minutes — double your exposure for each subsequent picture. At that rate, you will soon reach the point where the moon's apparent motion will record as a blur on your film unless your camera or telescope is clock driven — especially when true totality occurs, for then the required exposure will be 15 to 30 seconds! A possible answer with an undriven lens on the order of 300mm focal length is to use an ultrahigh speed film (such as GAF 500) for the total phase, and set your aperture wide open (typically f/4.0 to f/5.6 with such lenses) for a one to two second exposure... and hope!

One of the most interesting features of lunar eclipses is that no two are exactly alike, especially at totality. For reasons explained in the accompanying article, the exact light intensity of the eclipsed moon varies greatly with conditions in Earth's atmosphere. It is a matter of historical record that in at least one past eclipse, the moon was completely invisible even through a telescope at totality. For this reason, the exposure recommendations presented here are intended only for use as guidelines. Bracket your exposures to assure pleasing results, and you'll find the final product to be well worth its cost in discarded film.

One final word: Don't forget to send a few spare slides of the event our way!

ASTRO-NEWS

Latest News From the World of Astronomy

Light Shed on Star Birth

Star birth stubbornly remains one of the vaguest elements in current theories of stellar evolution. We can observe most stars in various stages of their fusion processes and even note violent supernova star deaths, but many events accompanying star formation have been obscure to earthbound instruments. New observational techniques are now uncovering a certain class of young stars called "cocoon stars".

"Cocoon star" is the name given — by astronomers Martin Harwit of Cornell University and Kris Davidson of the University of Minnesota — to certain apparently young stars which are hidden in the clouds of hydrogen and very fine dust particles that collapsed to form them. Because the light of these stars cannot penetrate the surrounding dust, and because the early cool burning of young stars does not produce radio emissions, these objects initially are visible only by infrared observation.

The difference between optical, radio and infrared astronomy is the wavelength of the photons being observed. Of all the types of electromagnetic radiation emitted by celestial objects — from gamma rays to radio waves — our atmosphere admits only a few kinds. These include a thin spectrum of visible light, a broader band of radio waves, and an assembly of infrared waves. The infrared and radio waves are not absorbed by dust, as light waves are. Infrared wavelengths are 10 to 20 times longer than those of visible light. People who study wavelengths of 1mm and longer are radio astronomers; wavelengths shorter than 1mm are considered to be the province of infrared astronomy.

The cocoon star begins as a loose collection of particles in the interstellar medium. Chance collisions of dust and hydrogen atoms, locked together by mutual gravitational attraction, build a protostar which grows by accretion as more dust from the freefall collapse of the cloud travels to its center. Before all the dust can be consumed, however, the star gains enough mass and heat to light up. Dust that was falling toward the protostar is slowed down, stopped, and then driven away by the pressure of the light shining from the new sun. The light catches the dust like wind filling a sail, billowing it into a protective canopy about the star. It is this dust front, heated by the starlight until it produces infrared emissions, that tells the astronomers a new star is being born.

The proof of the birth process is a visible new star, emerging from its cocoon hot and brilliant. But Harwit's theory will have to be proved by a successor, as the length of time required for any visible change in a star is about 10,000 years, and the oldest reliable infrared observation was made only 10 years ago.

The cocoons, Harwit said, probably

Birth *continued on page 58*

New Star Distance Sparks Look at Solar Neighborhood

A star previously believed to be about 50 light-years away is actually one of our closest neighbors — only 22 light-years distant. The new revision puts the small red dwarf star known as Gliese 625 among the nearest 100 stellar systems.

In some ways it is harder to get a good picture of our own neighborhood in space than it is to map regions thousands or millions of light-years away. The main reason is that we are in the middle of our own stellar neighborhood, and we can't get an outside perspective. Someone has said that trying to chart our local region in space is like trying to draw a map of New York City while standing in Central Park.

To attack this problem, the Dutch astronomer Jan Oort has studied the up and down motions (relative to the plane of the Milky Way) of stars near the sun. Ten years ago he showed that our local space must be much denser than had been thought — either our neighborhood is unusually cluttered with gas and dust, or there are many faint, nearby stars that haven't been discovered yet.

In an effort to remove the discrepancy, astronomers are taking a closer look at nearby space. They have found that a number of faint red stars are actually nearer than previously believed. The latest one to be pulled in closer is Gliese 625, a 10th magnitude red star in Draco.

When Gliese compiled his catalog in 1969, he assigned a distance of 47 light-years to star 625, on the assumption that it was a normal main sequence star. Now Arthur Upgren and his colleagues at Van Vleck Observatory in Middletown, Conn. have for the first time determined a trigonometric parallax for this star which puts it less than 22 light-years from the sun.

To be so dim so close, Gliese 625 must not be on the main sequence at all. Instead, it must belong in the category of subdwarfs — underluminous stars. This is confirmed by its almost total lack of elements heavier than helium. It must have been among the very first generation of stars formed in our region of space, before there were any heavier elements around to be incorporated into it.

Major Astronomical Advances Seen In Search for Extraterrestrial Life

Five years ago a major study to determine the most effective way to detect intelligent life beyond Earth was conducted by NASA's Ames Research Center. The study participants concluded that a gigantic "orchard" of 2,500 radio telescopes would be required to ensure a reasonable chance of success. The array, dubbed Cyclops, is pictured on page 11. Now one of the study's chief architects, Bernard M. Oliver of the Hewlett-Packard Company, has reviewed the astronomical potential of Cyclops and finds enormous possibilities.

Cyclops would represent an improvement over present radio telescopes that would be somewhat comparable to the superiority of the 200 inch telescope at Palomar over Galileo's best telescope. As yet, Cyclops is only a design study — no ground has been broken to build the first of its many telescopes and no site has been selected for its erection. But the capabilities of Cyclops, if and when it is built, provide a fascinating vista of future research.

The major purpose behind Cyclops is the detection of intelligent life beyond Earth. Scientists generally agree it is an essential step toward this goal — one that must be taken long before spacecraft are traversing the vast distances between the stars. For a price tag of about 1/2 that attributed to the Apollo project, Cyclops could be constructed over a period of 20 years or longer. However, it would be usable as soon as the first of its 330 foot dishes was completed.

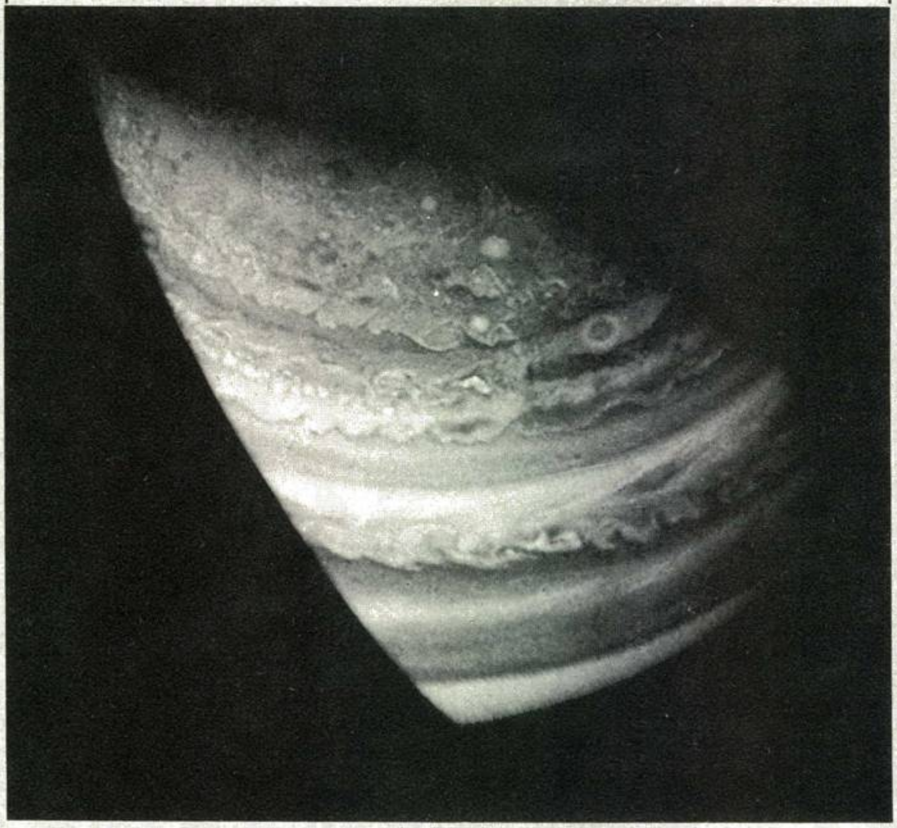
Certainly one of the reasons why there is not more pressure to build Cyclops is that the search for our cosmic contemporaries may require decades — perhaps even centuries — and there is no assurance of success. Although it seems likely that there are other intelligences in the universe (or even in our own galaxy), we do not know for certain that we are not alone.

In his recent update on the potential of the massive Cyclops system, Oliver maintains that vastly significant gains could be made in many areas of astronomical and space research if the telescope orchard is built. He cites many specific possibilities.

It will soon be within our capabilities to send an interstellar spacecraft to Alpha Centauri. When it arrives at that star system, the vehicle would have to send photos and other data to us across 4.3 light-years of space or 280,000 times the Earth-sun distance. To be heard by present equipment, the spacecraft would have to transmit with 100 million times the power that our current Mariner spacecraft have. Clearly this is impossible. With the Cyclops system, the spacecraft transmitter power would need to be raised only 160 times according to Oliver's calculations.

Cyclops could be used to map the surface features of every major object in the solar system by radar reflection techniques. Radar maps of Venus could be obtained with greater resolution than those we now have of the moon. "This may be the only way we can map the surface of Earth's sister planet with good detail and complete coverage," remarks Oliver. Craters on the major satellites of Jupiter and Saturn could be detected with this system and

New Jovian Detail



This view of Jupiter's cloudtops near the planet's north pole, taken by Pioneer 11, shows the greatest array of details ever seen of the giant planet's visible surface. Jupiter is a liquid planet and hence has no solid surface nor any "oceans" — only a gradual transition from atmosphere gas to liquid. The scalloped and swirling regions show sheer areas formed as the cloud belts and zones move around the planet at differing rates of speed. The white ovals show upwelling, while the dark ovals show downward movement of atmosphere. At the bottom of the photo (taken Dec. 2, 1974 at a distance of 375,000 miles), the south tropical zone is just barely seen. Going north above this white band is the equatorial region with its fast jet streams — some of them traveling 220 m.p.h. faster than the rotation rate of the planet. Direction of these atmosphere streams is to the right in the picture. Continuing north, a front of swirling "S" shaped cloud structures with billowing eddies forms because the jet streams vanish at this point. Above this front is the north tropical zone, which moves somewhat slower than the rotation rate of the planet. North of this zone, the dark north temperate belt shows a smooth southern boundary. But its scalloped northern boundary is dark and irregular, drawn out into ringed and circular features with sharp tips in between. Structures closer to the pole are less organized, but individual cloud features are clearly seen showing a combination of horizontal and vertical motion. The image was taken in blue light.

comets could be tracked to vast distances.

How would the Cyclops system compare as a pure radio telescope? The largest existing radio telescopes are the 1,000 foot dish at Arecibo and a 330 foot instrument in Germany. The VLA (very large array) under construction in New Mexico will comprise 27 dishes — each 85 feet in diameter — located along three 15 mile long arms in a "Y" configuration. Oliver emphasizes that although the VLA will be able to provide high angular resolution (that is, determine the specific shape of radio sources), its sensitivity for detecting faint objects will be less than that of the German 330 foot telescope. The Cyclops array, on the other hand, will have 6,000 times the sensitivity of the VLA.

Because of this increased sensitivity and the brute collecting surface area of Cyclops (equal to a single radio telescope, three miles in diameter), the radio astronomer could sit at a television monitor and receive *real images* of the object he is observing. Actual images of the hydrogen in nearby galaxies or gravitationally isolated clouds in our own galaxy could be observed in real time.

"It is hard to assess the importance of the dynamic interaction that would result between the astronomer and this kind of true radio telescope, but it seems certain that the discovery of new and fascinating phenomena would be greatly accelerated," comments Oliver.

The history of astronomy has shown that once an instrument is developed that extends the visible horizon dramatically, not only can more distant objects be discovered — but also previously unknown and exciting nearby objects are revealed. Cyclops, predicts Oliver, would reveal 1,000 times as many radio sources as any existing radio telescope including the VLA. "It is even possible that a Cyclops type system could detect the very first condensations to form and become luminous in the universe."

In the realm of stellar radio astronomy, the sensitivity of Cyclops would be sufficient to detect pulsars in neighboring galaxies. We could then map the pulsar density and distribution in different kinds of galaxies; this would give a strong clue as to the rate and type of star formation that has occurred in other stellar systems. Oliver notes that the observed frequency dispersion in pulsars in other galaxies would let us fix limits on the electron density in intergalactic space.

Nearer home, Cyclops would be capable of observing the corona and radio fluxes of stars like the sun. Stars that to us appear to look like the sun may or may not be like our star when observed in such detail with a giant radio telescope array.

The number and distribution of very faint stars in the galaxy is something that is constantly being revised and is still not well known. Very faint M class stars are about 1/10 the mass of the sun and hardly larger than Jupiter. Stars smaller than this are barely luminous and not detectable by methods used up to this time. With the Cyclops system, the low temperature radiation of an object somewhere in size between Jupiter's mass and 100 times Jupiter's mass could be detected up to tens of light-years away depending on how much time was applied to the survey.

If a nearby star like the sun has a planet similar to Jupiter, the giant array could detect it because Jupiter emits strong radio radiation. Cyclops would be able to discriminate that radiation from its parent star's noise at distances of 20 light-years and possibly farther.

Jovian Polar Atmosphere Promises Abode for Life

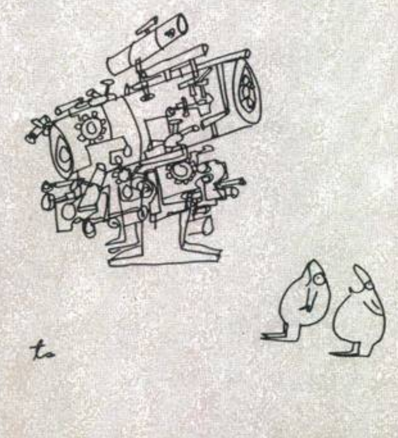
Observations of Jupiter's atmosphere show that many organic building blocks of Earth life are present, including water (see Astro-News, April 1975). But scientists suspect that extreme turbulence in the Jovian atmosphere may be one of the biggest obstacles to life on that gas giant world. Rapid, vertical atmospheric circulation would carry organisms from regions of comfortable pressure and temperature down into layers that are too hot to support life.

Recent photographs from Pioneer 11, the first space probe to fly over Jupiter's immense polar regions, reveal that the atmosphere circulates more slowly at the poles than at the equator. In contrast to the smooth equatorial cloud bands that flow along faster than Jupiter's rotation, the atmosphere at the polar regions appears mottled and irregular, indicating a more sluggish vertical and horizontal airflow. The combination of effects that could be producing these differences in atmospheric behavior — including Jupiter's great size, rapid rotation and high internal heat — have yet to be fully understood by planetary meteorologists.

But experts are now already suggesting that the relatively stagnant poles may be the best place to search for Jovian life. Pioneer 11's infrared measurements show that the upper cloud decks of the polar regions are only about five degrees Fahrenheit cooler than the equatorial belts. This is due to the fact that 2/3 of Jupiter's heat comes from high temperatures most likely generated by gravitational contraction at its interior. This heat uniformly spreads over the planet, making the poles as comfortable as the equator. Earth relies almost exclusively on the sun for heat. This energy arrives primarily at the equator, leaving the poles much colder.

Pioneer researchers also discovered that the polar cloudtops are substantially lower than the clouds at the equator, and are covered by a thicker transparent atmosphere. A blue sky is visible in these transparent regions, apparently caused by the same phenomena that produces Earth's blue sky — the selective scattering of light by atmospheric gases.

Since most theoretical models agree that Jupiter does not have a solid surface for supporting life, any organisms on that world would have to spend their entire existence suspended within the atmosphere. Pioneer's findings are the first promising hint that at least certain Jovian regions may be benign enough for aerial life forms to evolve.



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Birth *continued from page 55*

contain stars 10 to 30 times more massive than our sun. The luxury of their enormous size allows them to burn coolly at first, but as they continue to contract, they must burn with ever increasing heat to maintain energy equilibrium and keep from collapsing. The star's existence depends on preserving the delicate balance between energy output and the tendency toward gravitational collapse.

The star inside the blanket of dust has a surface temperature of at least 40,000 degrees Fahrenheit. The intense ultraviolet radiation strips the electrons off the nuclei of the surrounding gas molecules, creating a plasma of rapidly moving electrons and ions. The electrons, scattered by the positively charged ions, give off radio waves.

"Before this stage," Harwit said, "a cocoon star resembles many other kinds of bright infrared objects in space — particularly old giant stars."

Old stars appear very bright in the infrared region because they constantly spew out material which is blown away in the stellar wind. When this material is sufficiently far from the star, it condenses again into tiny dust grains. The dust, however, is not too far away to absorb the star's heat and glow with a warm red color. A new star can appear to have the same red glow, particularly when some of its light trickles through a hole in the cocoon; the blue light is scattered by the dust but the red shines deceptively through.

"The clue to the difference between dusty old stars and young cocoon stars is radio emission," Harwit said. "The radio signals show that the star is burning hotly enough to put out ultraviolet light and ionize the surrounding gases."

The types of stars detected through this combination of infrared and radio astronomy are the very bright massive stars. Could it be that these are the only types of stars being born? Or are our methods of detection not refined enough to discern smaller stars? Harwit feels there may be considerable differences between the way stars are formed now and the way they were born when the galaxy was young. The residue of heavy elements in the interstellar medium left by the explosive deaths of earlier generations of stars may make galactic conditions either more or less favorable for the production of massive stars — but astronomers are not sure which.

Unfortunately, we cannot examine *old* massive stars because all of them have long been gone. It is a characteristic trait of massive stars to burn furiously — producing thousands to millions of times the energy output of our sun, and exhausting their nuclear fuel in only a few million years. Some of the most massive stars lasted only 10,000 years. The sun, on the other hand, is much smaller and has passed through only half of its 10 billion year lifespan with judicious economy. The oldest stars we know of — nearly as old as the universe itself at some 15 billion years — are the members of the globular clusters. These great aggregates of stars contain as many as a million members, all comprised of only the lightest elements.

To date, the body of proof of the cocoon star theory is statistical. By observing regions in space like the Orion nebula that have several bright young stars associated with considerable dust, astronomers have also found very bright infrared objects coincident with compact thermal radio sources. If these objects are to be identified positively as stars being born, then further observations will be necessary.

"We are fighting for an infrared satellite," Harwit said. "There are no space vehicles yet equipped to do infrared astronomy. We need a more leisurely look at these objects than a five minute rocket or a rare 10 hour balloon flight can give."

Large optical telescopes like the 100 inch instrument at Mt. Palomar and the new 158 inch telescope at Kitt Peak can, with some conversions, be used for infrared observing at the shortest wavelengths, immediately adjacent to the visible spectrum. But the atmosphere cuts out nearly all the far-infrared emission through which the cocoon stars are trying to communicate their story.

A 120 inch telescope specifically intended for infrared observations is now under construction on the 14,000 foot peak of Mauna Kea, Hawaii. But even that instrument will only be an interim step. To learn more about the infrared universe, we will have to take the extra pains of observing with telescopes in Earth orbit.

Mariner 9 Provides No Key To Age of Martian Channels

One of the most exciting discoveries made by Mariner 9 was that riverlike channels are common surface features on Mars. Planetary scientists generally agree that these channels were shaped by running water. Since running water cannot exist under present Martian conditions, the channels seem to prove that violent climatic changes have been a part of the red planet's history. If the age of the channel could be determined, it would date the era of violent climatic change.

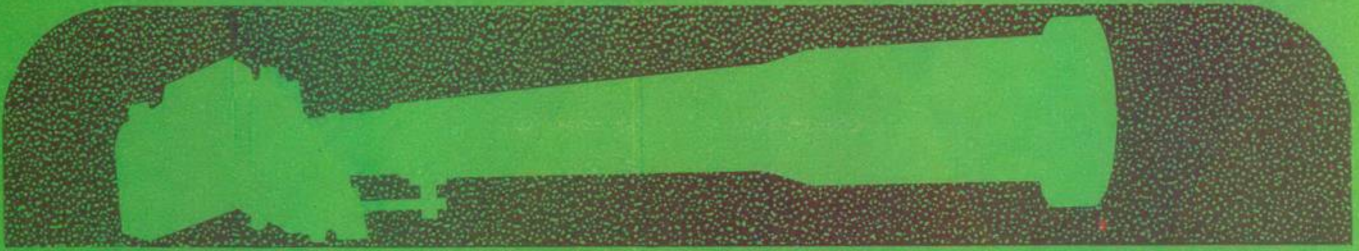
One extreme view is that the channels are very old, dating from the first billion years of the planet's history — when for a brief interval, Mars may have had a thick atmosphere produced by volcanic outgassing.

An opposing view is that severe climatic changes on Mars occur in 50,000 year cycles — the period with which the pole of Mars oscillates about its mean position. During the cold/dry phase of such a cycle, most of the atmosphere and water on Mars would be frozen out in the polar regions, and liquid water would not exist on the planet. Hence, no channels could be cut. During the warm/wet phase, the volatiles would be released from the polar regions. The atmosphere would become thick and perhaps rich in water; liquid water on the surface would then carve channels. According to this picture, the youngest channels on Mars may be less than 100,000 years old. (For details see "The Canals of Mars", April 1974.)

The only means of actually dating the channels at present is by counting the crater density on their floors. W. K. Hartmann of the Planetary Science Institute in Tucson, Ariz. reported at a recent American Astronomical Society meeting that all channels in which he was able to count craters (using Mariner 9 photos) reveal calculated ages considerably in excess of 50,000 years, and therefore do not suggest the short-period model of climatic oscillations on Mars.

But can the channels be as old as four billion years? Hartmann suggests the answer to this question depends on the rate at which craters are formed on Mars by collisions with interplanetary debris. Only if the cratering rate on Mars has been as low as that on the moon do the channels come out to be several billion years old. Since Mars is close to the asteroid belt, Hartmann estimates that the cratering rate on Mars has in fact been higher than that on the moon — a good guess is about 10 times higher. Thus, the age of the channels can be brought down by a factor of 10 to a few hundred million years.

There appears to be no way to make the ages come out to be as low as 100,000 years — a bad omen for the oscillating climate theory.



PHOTOGRAPHY IN ASTRONOMY

Astrophotographic Routes

by

Leo C. Henzl Jr.

Where to go in astrophotography and how to get there are among the queries most often posed by novices wondering how to get started, and by veterans looking to expand in new directions. Summarized in the chart which follows are equipment and sky condition requirements, as well as various other essentials, for the six basic astrophotographic systems in common use. First, a general look at each of the systems.

The Stationary Camera

All equipment required here is strictly photographic rather than astronomical — and is likely to be found in any snapshooter's gadget bag. Most cameras capable of taking time exposures will be satisfactory for one project or another, with single lens reflex (SLR) cameras affording no particular advantage. In fact, the generally brighter viewing image of a rangefinder type may prove superior for use in the dark.

Exposure durations tend to fall into two distinct categories — fairly short, and very long. With brief exposures from about 10 to 30 seconds, the stationary camera records the sky much as we perceive it without optical aid. Longer exposures — typically from 30 minutes to several hours — render stars as concentric trails, often punctuated (fortuitously) by the crosswise passage of satellites and meteors, or (less fortuitously) by wandering aircraft.

In planning projects for photography of this sort (or of any other sort, for that matter), it's helpful to know the angular field coverage in degrees of your camera and lens combination. This involves a simple calculation, similar to that for eyepiece field determination in last month's Equipment Atlas. Requisite data are the dimensions of your film format and the effective focal length (EFL) of your camera lens. The actual picture area of a standard 35mm camera is 24mm x 36mm, and Pythagoras tells us that the diagonal measurement of this rectangle is about 43mm. Let's say, for example, that your 35mm camera is equipped with a 50mm "normal" lens. Here's the calculation:

$$\text{field coverage} = \frac{57.3}{\text{lens EFL (mm)}} \text{ x } \begin{array}{c}\text{film format}\\ \text{dimensions (mm)}\end{array}$$

$$= \frac{57.3}{50\text{mm}} \begin{array}{l}\text{x } 24\text{mm} = 27.5^\circ \text{ vertically}\\ \text{x } 36\text{mm} = 41.3^\circ \text{ horizontally}\\ \text{x } 43\text{mm} = 49.3^\circ \text{ diagonally}\end{array}$$

Very dark sky conditions are essential with the long exposures involved for meteors and star trails, but are relatively unimportant for the shorter exposures of constellation photography. This, then, is at least one activity you should be able to enjoy even from a metropolitan area.

The Piggyback Camera

In its most simple form, piggyback photography is a close relative to photography with a stationary camera. Typical subjects are of similar angular extent, and though a clock driven telescope is employed, it serves only as a moving tripod while the camera's optics still do the real work. The difference, of course, is that exposure times for constellations and star fields may be extended to 30 minutes or more, thereby recording stars and nebular objects far below naked eye visibility — often to 10th magnitude or fainter. Exceptionally dark skies are essential for best results, but "seeing" is unimportant with the usual "normal" and telephoto lenses. Such lenses are also very forgiving of guiding and polar alignment errors, so the piggyback method is an excellent initiation for guided photography in general.

Though the term piggyback normally denotes an ordinary camera riding atop a telescope, another popular configuration is photography through a small telescope of low numerical f-ratio, mounted coaxially to a larger instrument, used for guiding —

typically, perhaps, a five inch f/4.0 reflector riding on a eight incher. This arrangement has much to recommend it: Small reflectors can often cover three degrees or more of sky and thus produce truly spectacular photographs of open star clusters and extended nebulae. Exposures are generally brief with such "fast" systems, and their short focal lengths are fairly insensitive to guiding errors and poor seeing. A piggyback Schmidt camera offers similar advantages, coupled with extreme photographic speed and superb correction across its entire field. On clear nights when atmospheric scintillation (all too often) renders your main telescope photographically useless, versatile auxiliary instruments such as these can still make for some very exciting astrophotography.

The Afocal Camera

The afocal method is the only form of photography *through* a telescope in which a camera lens is part of the system. Procedure for the method consists of focusing your telescope sharply on the desired target, and then positioning your camera with its lens focused for infinity over the eyepiece for actual photography.

Simple though the system may be, it is also highly versatile. With a varied selection of oculars and camera lenses, you can achieve a wide variety of EFLs normally regarded as the provinces of the more popular first-focus and positive projection systems. The effective focal length of an afocal system is the simple product of your telescope's visual magnification and the focal length of your camera lens. Let's assume that you are using an ocular that yields 40 power with your six inch (150mm aperture) reflector, and that your camera lens is of 50mm EFL.

$$\text{afocal EFL (mm)} = \text{visual magnification} \times \text{camera lens EFL (mm)}$$
$$= 40 \times 50\text{mm} = 2{,}000\text{mm}$$

To determine exposure, you'll also need to know the effective focal ratio of your system. Using numbers from the example above:

$$\text{f-ratio} = \frac{\text{afocal EFL (mm)}}{\text{telescope aperture (mm)}}$$
$$= \frac{2{,}000\text{mm}}{150\text{mm}} = \text{f/ } 13.3$$

With this particular combination, the full moon fits nicely onto a 35mm negative and, with a fairly fast film, could be photographed with an undriven telescope.

With oculars of higher power and camera lenses of longer focal length, the afocal system may also be used for small scale objects like planets and individual lunar features. If that six inch scope we've been discussing was coaxed to 150 power and used afocally with a 135mm telephoto lens, the resultant EFL would be a monumental 20, 250mm — enough to render an image of Jupiter nearly 4.5mm in diameter! Calculation shows, though, that this is an f/135 system, so a clock drive would be necessary for an exposure a few seconds in duration.

With this kind of versatility, you might wonder why serious astrophotographers generally employ first-focus and projection systems in preference to the afocal method. There are several reasons — the primary being the number of optical elements involved. A typical camera lens may have six or more elements, and an ocular four — a total of 10 or more pieces of glass intervening between subject and film, each taking a small bite out of potential resolution and contrast. (Nevertheless, we've seen some afocal photos whose quality seems to belie optical theory.) Other problems include inevitable edge vignetting with some (usually low power) ocular and camera lens combinations, and generally awkward mounting hardware required to couple camera and telescope.

The First-Focus Camera — Unguided

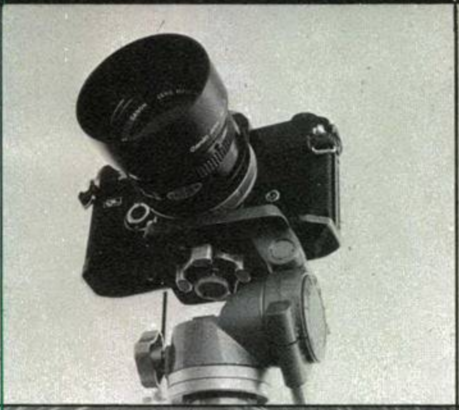
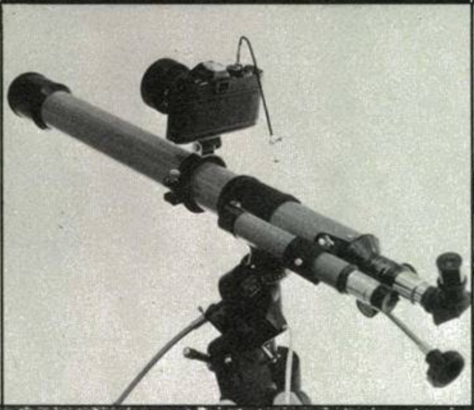
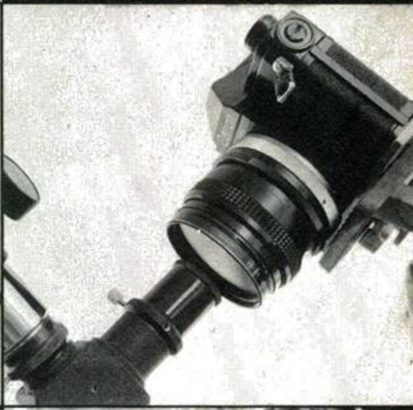
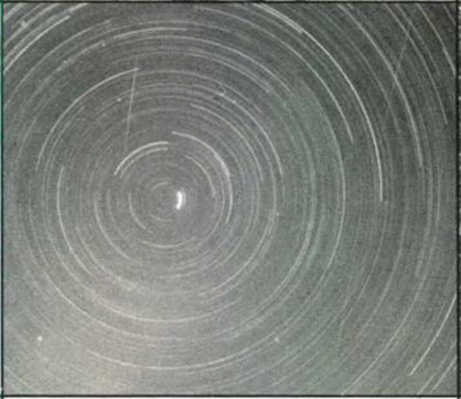
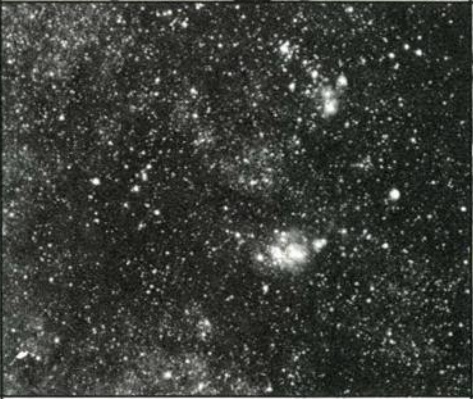
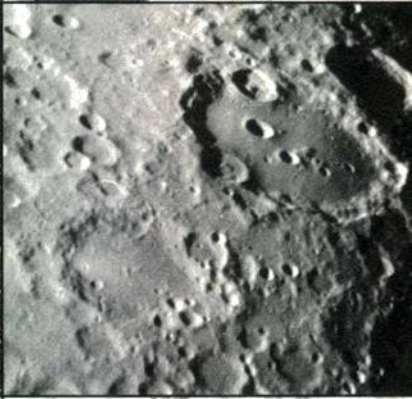
The first-focus system is often referred to by different terms — prime focus, direct objective, Cassegrain focus, and Newtonian focus, to name the most common. Whatever we call it, though, the idea is to intercept a telescope's beam at the first point a real image forms. For this, an SLR camera body with a focal plane shutter is attached with an appropriate coupling; the telescope becomes, in effect, a superlong telephoto lens. The hardware involved is often a simple camera-to-ocular drawtube adapter. But, because such adapters impose a restriction of lesser aperture than the film dimensions, they generally produce some edge vignetting, especially severe with the small diameter drawtubes of most imported telescopes. Ideally, the coupling should have a clear aperture of at least 40mm all the way through — but vignetting may not prove troublesome if you take care to center your subject in the camera's field.

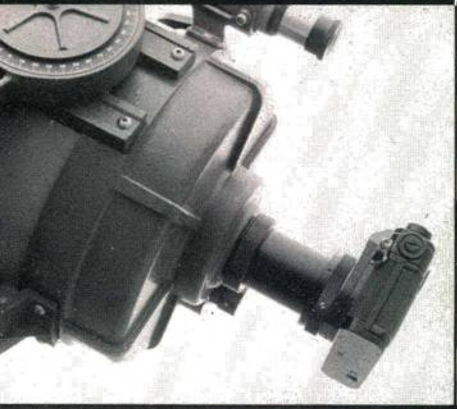
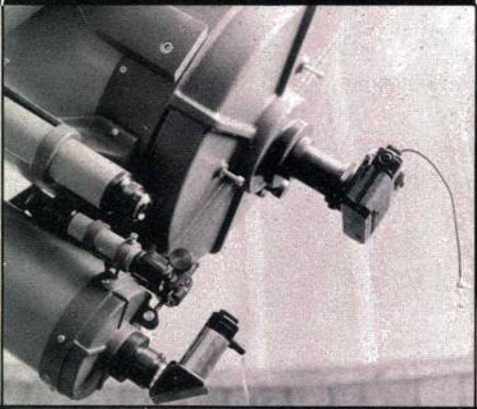
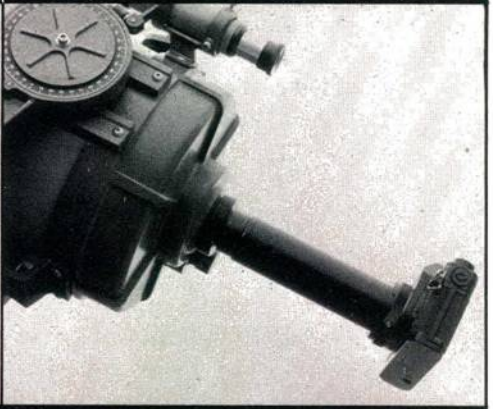
Another problem of a design nature sometimes occurs in trying to use a Newtonian reflector for first-focus photography. The focusing drawtube does not have enough inward travel to allow a focused image to reach the camera's film plane. Remedial action is to move the primary mirror forward the required distance — either with an adjustable mirror cell, or by drilling new mounting holes for the existing cell farther up the tube. Image plane accessibility is not usually a probelm with the long drawtubes of refractors or the movable focal planes of catadioptric telescopes.

Though we have labeled the system under discussion as unguided, the telescope employed may

The easiest type of celestial photography — using a stationary camera — can yield pleasing portraits of the constellations that practically duplicate their unaided eye appearance. Here, Orion is captured in a 15 second exposure on High Speed Ektachrome using a Minolta SRT-101 with a 50mm f/1.7 lens.

ASTROPHOTOGRAPHIC SYSTEMS

	Stationary Camera	Piggyback Camera	Afocal Camera
Equipment Setup			
Representative Photo			
Typical Subjects	constellations; star trails and meteors; aurorae; solar and lunar eclipses	constellations in detail; large scale nebulae and star fields	same as for unguided first-focus and positive projection systems
Equipment Requirements	1. camera with time exposure capability and f/4.0 or faster lens 2. tripod 3. locking cable release	1. clock driven telescope — any aperture 2. camera with f/4.0 or faster lens 3. camera mounting bracket 4. locking cable release 5. drive corrector 6. guiding (cross hairs) ocular 7. declination slow motion helpful for best results	1. telescope of any aperture — driven or undriven 2. camera with adjustable shut — SLR preferred 3. camera mounting bracket 4. remote shutter release — air-type preferred
Sky Requirements	reasonable transparency; seeing unimportant	excellent transparency; seeing relatively unimportant	good to excellent seeing; transparency unimportant
Typical Films	B & W or color — ASA 100 or faster	B & W or color — ASA 100 or faster	B & W or color — ASA indices suitable for one subject or another
Typical Exposures	10 seconds to 2 hours f/1.4 to f/16	5 to 45 minutes f/1.4 to f/5.6	1/500 to 10 seconds f/10 to f/150
Primary Problems	lens dewing in longer exposures; wandering aircraft	accurate polar alignment and guiding; lens dewing; wandering aircraft	shutter vibration; field vignetti excess number of optical eleme in system

First-Focus Camera Unguided	**First-Focus Camera Guided**	**Positive Projection Camera**
		
full disk of sun and moon; lunar occultations; satellite configurations of planets	small scale nebulae and star clusters	planetary detail; individual solar and lunar features
1. telescope of any aperture — driven or undriven 2. SLR camera body 3. camera-to-telescope adapter 4. remote shutter release — air-type preferred	1. clock driven telescope of four inch aperture or more 2. SLR camera body 3. camera-to-telescope adapter 4. locking cable release 5. guiding system — either off-axis guider or auxiliary guide-scope 6. drive corrector 7. declination slow motion	1. clock driven telescope — generally of three inch or greater aperture 2. SLR camera body 3. ocular projection adapter ("telextender") 4. remote shutter release — air-type preferred 5. drive corrector for lunar photos at extreme EFLs
good to excellent seeing; transparency unimportant	good to excellent seeing and transparency	excellent seeing; transparency unimportant
B & W or color — all ASA indices, but slower films preferable	B & W films of ultrahigh speed; color generally requires chilling ("cold camera")	high resolution B & W and color films
1/500 to 30 seconds f/4.0 to f/20	10 minutes to 2 hours f/4.0 to f/15	1/30 to 10 seconds f/20 to f/150
shutter vibration; polar alignment with longer exposures; critically sharp focus	accurate polar alignment and critically sharp focus; lens dewing	accurate polar alignment; clock drive irregularities; shutter vibration; critically sharp focus

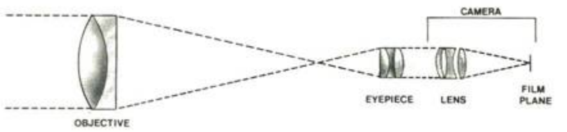
very well be clock driven. The distinction is drawn only because of the very different parameters involved in long exposure first-focus photography, discussed in the following section. Typical subjects in the unguided mode include the full disk of the moon and (with appropriate filtration) the sun. With medium and high speed films for exposures of 1/60 second or less, a clock drive is unnecessary — but most photographers will want to exploit the inherent crispness of first-focus images with slower, finer grain emulsions. Good seeing is a prerequisite for best results, but not necessarily the near-ideal conditions needed with the extreme effective focal lengths of projection photography. Transparency and dark skies are of relatively little importance for most subjects, so here again is an area in which city dwellers can hope to excel.

The First-Focus Camera — Guided

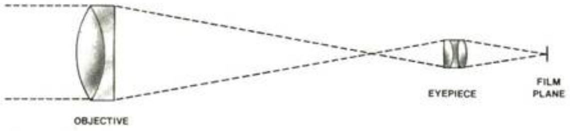
Though the optical hook-up for this system is the same as that of its predecessor, the similarity ends there. The deep sky targets of the guided camera are dim indeed, so very fast films and lengthy exposures are the essentials here. Because tracking errors due to atmospheric scintillation and refraction, clock drive irregularities, and polar misalignment would accumulate in the course of a long exposure if the camera was simply left unattended, it is necessary to monitor a guide star constantly with an off-axis guiding system or separate guidescope, making frequent guiding corrections. Although this is essentially the same procedure employed in piggyback photography, the EFLs of first-focus photography are many times greater, so the requirements for accurate guiding are correspondingly more demanding. As a general rule, precise guiding will require a minimum magnification at least two times your first-focus EFL in inches — for example, 100 power to guide a 50 inch EFL system. This is a bare minimum, and guiding is likely to prove more accurate and less tiring with ratios of three or four to one.

ASTROPHOTOGRAPHY:
Telescope-Camera Optical Arrangements

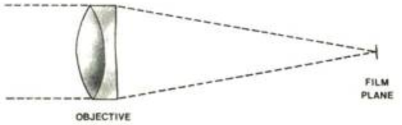
Afocal



Positive Projection



First Focus



The requirements for sky conditions in guided photography are also more stringent than for most of the other systems discussed. Best results come only with that all too rare combination of excellent seeing and transparency.

The Positive Projection Camera

With this system, an ocular and an extension tube — inserted between the telescope and the SLR camera body — are employed to attain greater EFLs than the first-focus method can provide. The principle of the system is identical to that of slide or movie projection: Think of the first-focus image as a slide positioned in a projector's gate, the ocular as the projection lens, and film as the projection screen. As in the analogy, magnification at the film plane depends on the EFL of the projecting ocular and on the ocular-to-film distance. The shorter the ocular's EFL and the greater its distance from the film, the larger the resultant image.

To calculate projection EFLs and f-ratios, it is convenient to determine first the *projection factor* for a given combination of ocular and projection distance — that is, the ratio of scale difference between your first-focus image and projection image. Assume that you're using a 25mm ocular with projection hardware providing a 150mm ocular-to-film distance. (Make this measurement from the center of the ocular.)

$$\text{projection factor} = \frac{\text{projection distance (mm)}}{\text{ocular EFL (mm)}} - 1$$

$$= \frac{150\text{mm}}{25\text{mm}} - 1 = 5\text{x}$$

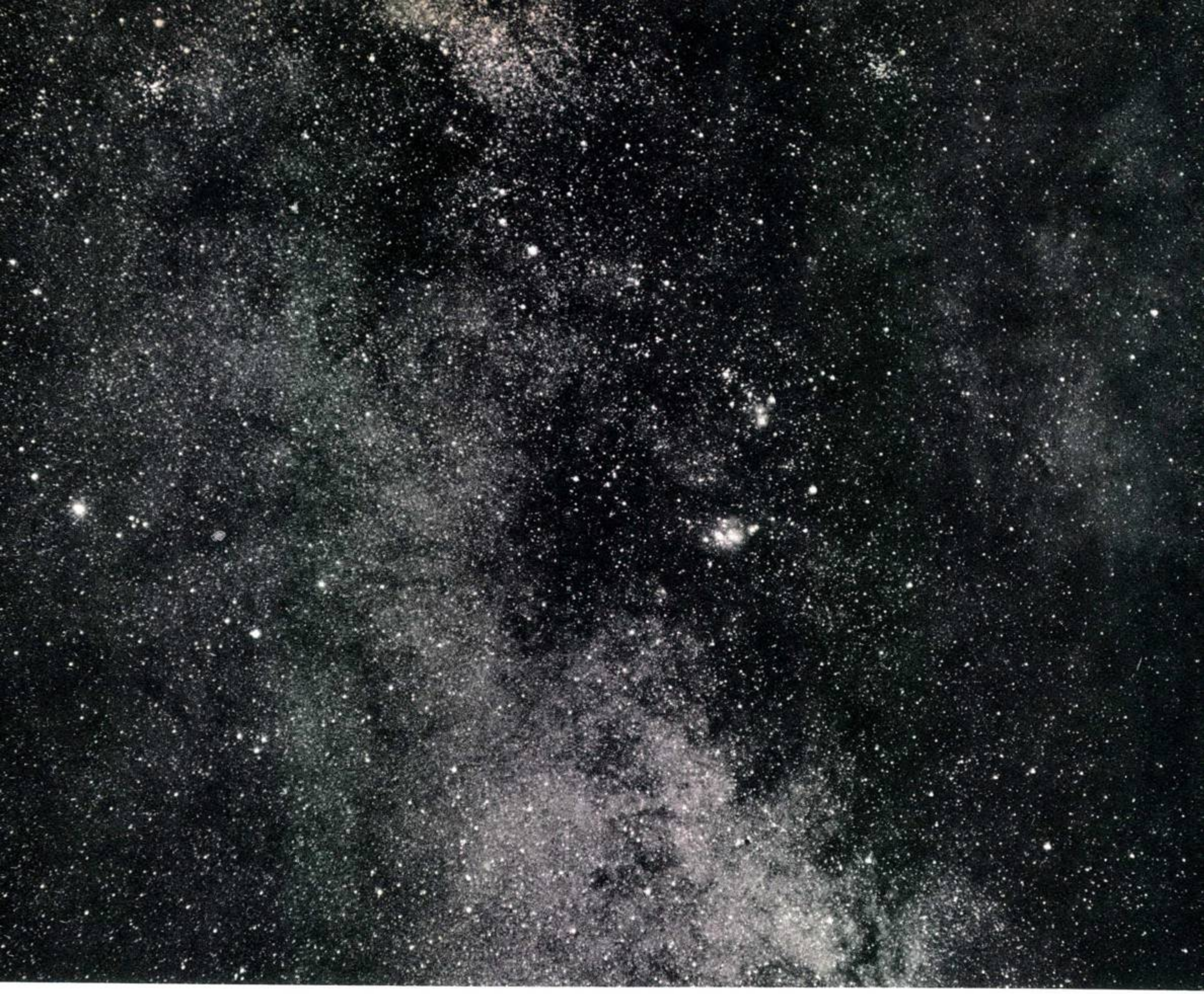
In this instance, the projected image will be five times the linear size of the first-focus image.

Once you've determined the projection factor, the remaining calculations are simple. Let's say your telescope has a first-focus EFL and an f-ratio of 2,000mm and f/10. Multiplying these numbers by the projection factor will give you the projection EFL and f-ratio:

projection EFL (mm) = first-focus EFL (mm) x projection factor
2,000mm x 5 = 10,000mm

projection f-ratio = first-focus f-ratio x projection factor
f/ 10 x 5 = f/ 50

Positive projection is normally employed for small scale subjects demanding high resolution. Such photography is difficult in general and requires nearly perfect seeing, as well as fastidious attention to details of technique. Again, though, transparency isn't especially important. Some of the finest amateur planetary portraits have been shot through the



Photograph by John Sanford

The Milky Way in Sagittarius is one of the sky's richest regions and a favorite area for both photographic and telescopic exploration. Near center is the massive Lagoon nebula (M-8) with the smaller Trifid (M-20) above it. The open cluster M-23 is at the upper right. Remarkably unsophisticated equipment was used for this observatory-quality photograph: a 35mm camera equipped with a 105mm Nikkor lens mounted piggyback on an eight inch Celestron telescope. The Kodak Tri-X film was exposed for 16 minutes and developed in Microdol-X. Exceptionally clear skies, were, of course, helpful.

stable mass of smog that so often hangs over our cities during temperature inversions in warm months.

In writing of this system, the excessive use of qualifiers such as "normally" and "usually" has been deliberate, because there is one special case of positive projection wherein the method actually *reduces* a telescope's EFL. If the lens-to-film distance is less than the EFL of the projection lens, the result will be a *negative projection* factor. Packaged commercially, such a lens is referred to as a *telecompressor* to distinguish it from the usual *telextender* (or projection tube). In reducing a telescope's net EFL typically by 50 percent or so, it also diminishes the instrument's numerical f-ratio by the same factor — the result being greatly shortened exposure times for deep sky photography. Because a telecompressor demands a large amount of focus travel, its use is generally confined to catadioptric telescopes with movable focal planes.

True negative projection involves the use of a Barlow lens (which has a negative EFL) in place of an ocular. This method is sometimes used for modest gains in EFL, but the physical design of many commercial Barlows causes severe vignetting. In general, to achieve a given EFL, the positive method will be preferable.

Though many photographers will choose to specialize in one or another of the fields discussed — either for reasons of inclination, budget, or location — the possible routes in astrophotography are so varied that a modest variety in equipment choice can make for rewarding diversion on almost any cloudless night and from almost any location.

[illegible] locate any celestial object

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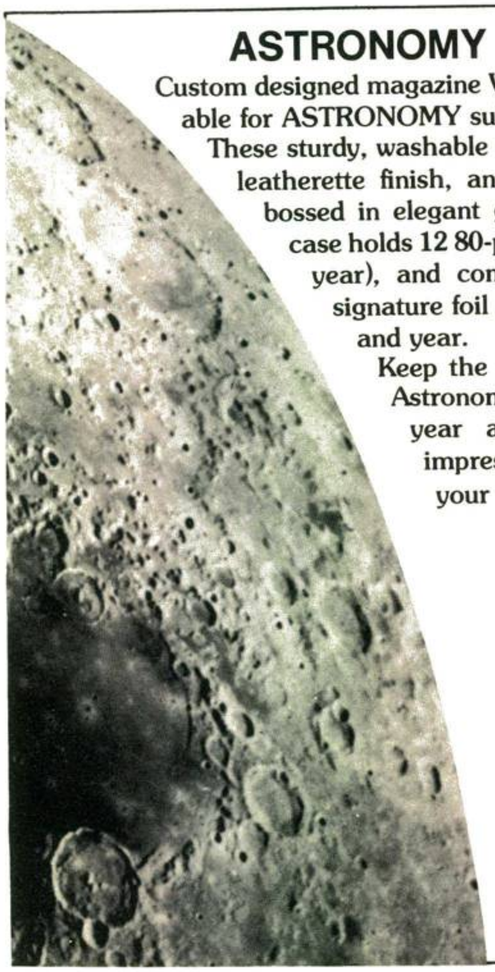

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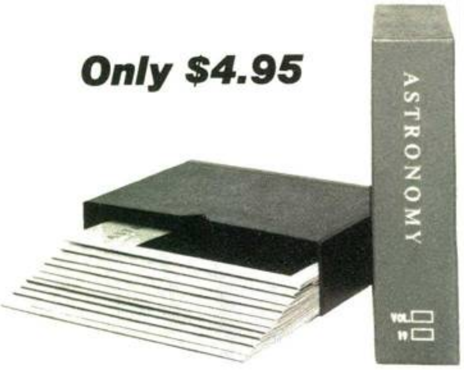

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STAR DOME

MAY

Returning warm nights tempt even occasional stargazers to emerge from their winter hibernation and get reacquainted with the constellations. At first glance the spring skies may not seem too rewarding for the effort. To fully explore and enjoy the spring skies, this season — more than any other — demands driving into the country on a clear night.

Centerpiece of the May Star Dome, Leo the lion can be found high in the southern sky. An unmistakable backward question mark pattern of six stars outlines Leo's head. You can't miss one of the spring sky's brightest beacons at the bottom of the question mark — first magnitude Regulus. About as distinct as Leo's "sickle" is a right triangle of three stars off to the left of his head. It identifies the lion's hindquarters, with second magnitude Denebola marking the tip of his tail.

Some stories say that Leo's Earthly cousins are responsible for placing him among the star patterns. Ancient Egyptians noted that in midsummer (in that era), when the sun was in Leo's location, lions left the desert to seek cooling relief on the banks of the Nile. Egyptians also worshipped the stars in Leo — because during summer the Nile flooded, resupplying the land with fertile soil.

Greek mythology hints that Leo was some kind of extraterrestrial visitor. Like a shooting star, the lion supposedly fell from the skies and into the Valley of Nemea. Having a hide impervious to the strongest arrows, Leo terrorized the valley's inhabitants. In a struggle lasting 30 days (the length of time the sun passes through Leo), the Greek warrior Hercules sought to kill the creature. All Hercules' weapons against the superlion failed. Finally the avenging beast leaped toward the warrior. Hercules' powerful hands grabbed Leo's throat, choking it to death. The doomed beast was carried back to its home in the sky and transformed into a constellation. Leo is placed near two other casualties of combat with Hercules — Hydra the dreaded water serpent, and Cancer the crab.

East of Regulus and Denebola are two other very bright stars of the May sky — Arcturus (arc-TOUR-us) and Spica (SPY-ka). Finding them involves first locating the Big Dipper, suspended high above the northern horizon this season. Following an arc from the dipper's three handle stars leads directly to yellowish Arcturus, the brightest star in the constellation Bootes (bow-OH-teez) the herdsman, or bear driver.

At zero magnitude, Arcturus ranks as the fourth brightest star in the northern hemisphere. With a surface temperature of only 7,000 degrees Fahrenheit — about 2/3 of our sun's surface temperature — Arcturus nevertheless blazes 110 times brighter than the sun. It may seem puzzling to think of something cooler as being brighter; if a square foot of the sun's surface was placed beside a square foot of Arcturus' surface, the sun's would be more luminous. In reality, what Arcturus lacks in temperature it makes up for in size. This giant star measures 23 times larger than our sun, meaning that it has about 500 times more surface area.

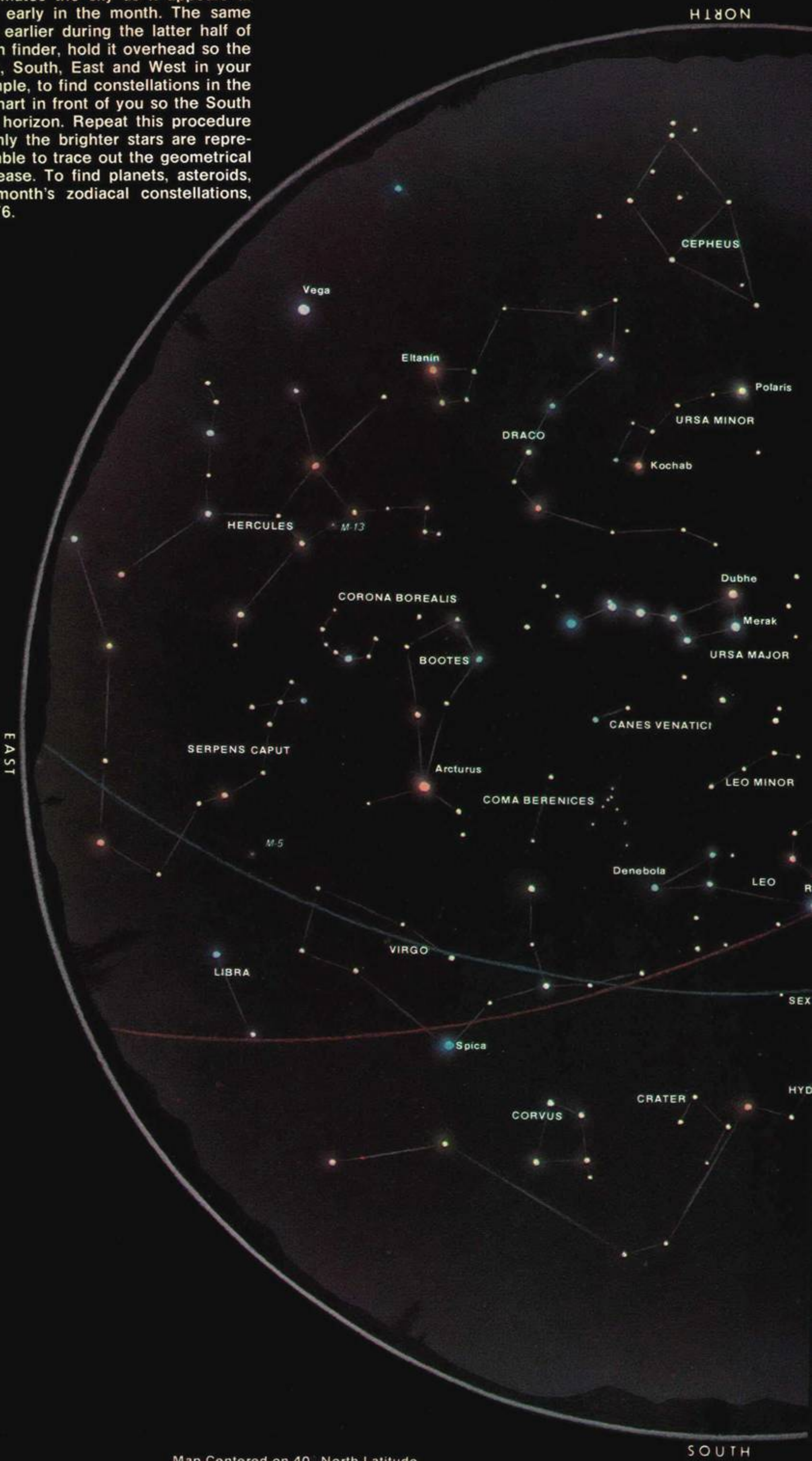
Bootes is usually pictured as driving the big bear, Ursa Major (of which the Big Dipper is a part), across the heavens. One hand holds a staff while the other hand controls a leash for his two hunting dogs Asterion and Chara in the constellation Canes Venatici. Other ancient interpretations picture Bootes as pushing his newly invented plow across the sky.

One story in mythology describes Bootes as really being Icarus, the rich owner of a grape vineyard. One day the god Bacchus showed Icarus how to put his grapes to a more productive and entertaining use — through winemaking. Icarus eagerly introduced his friends to this new found heavenly beverage. Icarus drank, and the party goers drank, and drank — and drank! Since his guests were completely unfamiliar with the effects of alcohol, Icarus' party must have been the wildest thing that Greece had seen in 1,000 years.

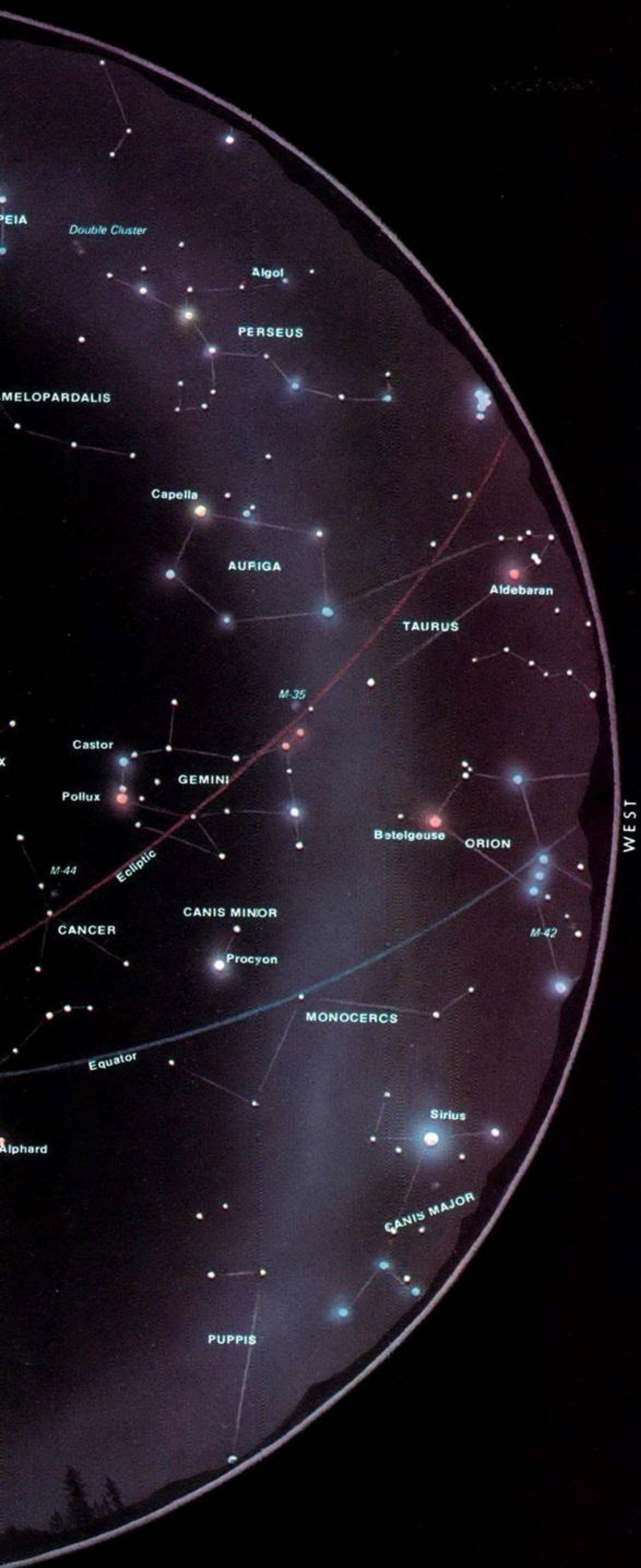
It was not so funny the next morning when his sloshed friends awoke. Not being familiar with what a hangover was, they hastily concluded that Icarus had tried to murder them — so they returned the favor.

Icarus' daughter Erigone and his two hunting dogs eventually found his body. In anguish, Erigone killed herself and the dogs stayed permanently beside their master. Bacchus transformed Icarus into the constellation Bootes, the dogs into Canes Vena-

This Star Dome rendering approximates the sky as it appears at about 9 p.m. Local Daylight Time early in the month. The same constellations are visible one hour earlier during the latter half of the month. To use this constellation finder, hold it overhead so the compass points line up with North, South, East and West in your backyard or viewing area. For example, to find constellations in the southern part of the sky hold the chart in front of you so the South compass point faces the southern horizon. Repeat this procedure for East, West and North. Since only the brighter stars are represented in this map, you should be able to trace out the geometrical shapes of the constellations with ease. To find planets, asteroids, etc., visible among the current month's zodiacal constellations, refer to the planet finder on page 76.


NORTH
CEPHEUS
Vega
Eltanin
Polaris
URSA MINOR
DRACO
Kochab
HERCULES
M-13
Dubhe
CORONA BOREALIS
Merak
BOOTES
URSA MAJOR
CANES VENATICI
EAST
SERPENS CAPUT
Arcturus
LEO MINOR
COMA BERENICES
M-5
Denebola
LEO
R
VIRGO
LIBRA
SEX
Spica
CRATER
HYD
CORVUS
SOUTH

Map Centered on 40° North Latitude



Map by Adolf Schaller

tici, and Erigone into Virgo. Every night Virgo and the dogs rise to search for Bootes.

Virgo the virgin can be located by continuing the arc through Arcturus and on to Spica — "arc to Arcturus and speed on to Spica", as the familiar phrase goes. In several ancient cultures, a heroine in mythology or folklore occupies the location of Virgo. As a spring constellation to the ancients, the maiden symbolized a reawakening of nature and a sense of youthfulness and fertility.

Greek mythology portrays Virgo as Demeter, the goddess of Earth. An early Greek poem tells of the kidnapping of Demeter's daughter Persephone by the god Hades. As ruler of the underworld kingdom of the dead, Hades sought to make Persephone his queen. Grief-stricken, Demeter withheld her gifts of fertility. For more than a year nothing grew despite farmers' efforts, and the land was transformed into a frozen wasteland.

Finally Zeus, king of the gods, demanded that his brother Hades free Persephone. Reluctantly Hades released his queen, but because she had eaten some of the fruit of the underworld she was magically bound to spend part of each year with him. Virgo appears every spring when Persephone happily rejoins her mother, and Earth again blossoms. When the daughter must return to the underworld, Virgo disappears below the horizon and winter returns.

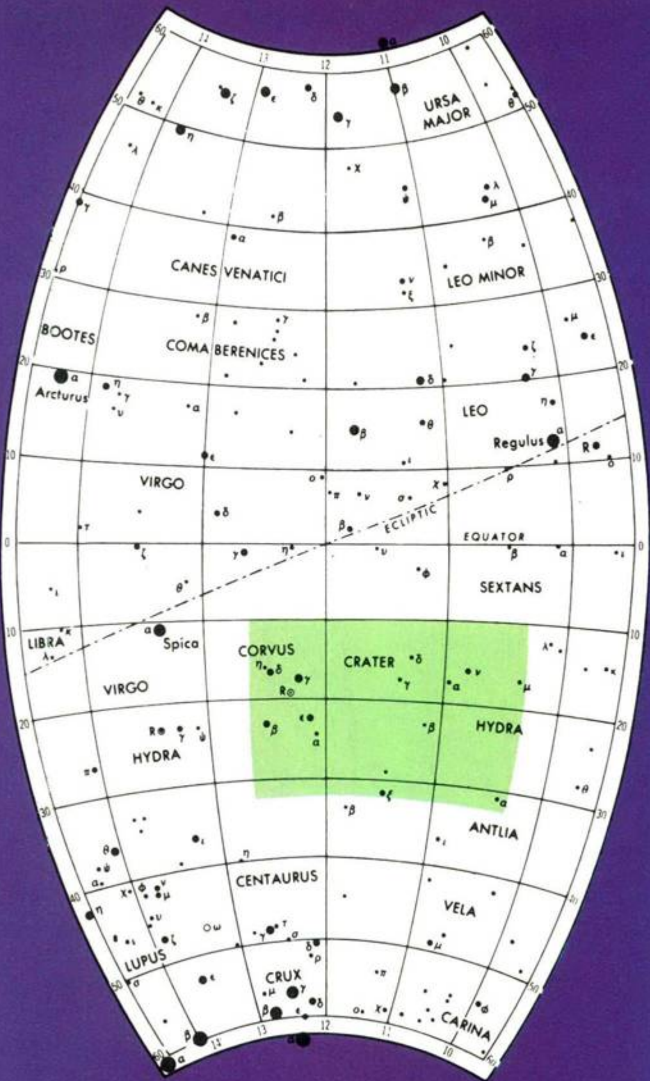
As with most constellations, Virgo hardly resembles its namesake. Most old star maps show her as a winged maiden holding a sheaf of wheat or corn in her left hand. Brilliant blue-white Spica (meaning "ear of wheat") locates the left hand.

A special geometric pattern of stars is associated with each season — a triangle in summer, a square in autumn, and a circle in winter. For spring we can construct the so-called "diamond of Virgo" by connecting Arcturus, Spica, Denebola and Cor Caroli, a third magnitude star in Canes Venatici — which lies about halfway between Leo and Bootes.

Our arcing path ends at Corvus the crow, a pet of the Greek god Apollo. While most mythological creatures are placed in the heavens as honor, Corvus is up there for eternal punishment. Mythology explains that Apollo caught the bird lying about why he was late on an errand to fetch a cup of water. As punishment, Apollo placed Corvus in the sky along with the cup, in the form of the constellation Crater. Although Crater lies just to the right of Corvus, Hydra the water serpent forever keeps the thirsty bird from drinking out of Apollo's cup.

Close-Up on the Corvus/Crater Region

Compared to some of the other regions we have focused on in recent months, the section of sky we know as the constellations Corvus and Crater is


URSA MAJOR
CANES VENATICI
LEO MINOR
BOOTES
COMA BERENICES
Arcturus
LEO
Regulus
VIRGO
ECLIPTIC
EQUATOR
SEXTANS
LIBRA
Spica
CORVUS
CRATER
VIRGO
HYDRA
HYDRA
ANTLIA
CENTAURUS
VELA
LUPUS
CRUX
CARINA

Stars in each constellation are indicated, in order of brightness, with the Greek Alphabet

α	Alpha	η	Eta	ν	Nu	τ	Tau
β	Beta	θ	Theta	ξ	Xi	υ	Upsilon
γ	Gamma	ι	Iota	ο	Omicron	φ	Phi
δ	Delta	κ	Kappa	π	Pi	χ	Chi
ϵ	Epsilon	λ	Lambda	ρ	Rho	ψ	Psi
ζ	Zeta	μ	Mu	σ	Sigma	ω	Omega

Star Magnitudes

—1
0
1
1½
2
2½
3
3½
4
5

○ Cluster or Nebula

⊙ Variable Star

Map from **Guideposts to the Stars**; reprinted permission of MacMillan Publishing Co., ©1972 by Leslie C. Peltier.

TABLE OF OBJECTS - CORVUS CRATER REGION

Double Star

Star	Mag.	Sep.	R.A.	Dec.
Δ Corvi*	3.1, 8.4	24"	12^h27^m	-16°14'

Variable Stars

Star	Mag. Range	Period	Type	R.A.	Dec.
U Hydrae*	7 to 9	450 days	semiregular	10^h35^m	-13°07'
R Corvi	7 to 14	317 days	long-period	12^h35^m	-19°15'

Clusters, Nebulae, Galaxies

NGC	Type	Mag.	Size	R.A.	Dec.
3242*	Planetary	9	40"x35"	10^h22^m	-18°23'
3923	Elliptical galaxy	11	90"x70"	11^h48^m	-28°33'
4361*	Planetary	11	80"	12^h22^m	-18°29'
4590 (M-68)	Globular cluster	8	3'	12^h37^m	-26°29'
4594 (M-104)*	Spiral galaxy	9	6'x3'	12^h37^m	-11°21'

* Detailed description in Eyepiece Impressions

Right Ascension and Declination Epoch 1950 dim and unattractive. However, this is only partly true. As you will see in Eyepiece Impressions, there are some interesting and rather neglected objects in this area.

However, observer Jim Mullaney admitted when compiling that section that the constellation Crater is the nearest thing to a wasteland as found anywhere in the sky. It contains no interesting double stars, no galactic clusters, no globular clusters, no planetary or diffuse nebulae and no galaxies above 11th magnitude. We are finally forced to say that unless you are a diehard visual catalog compiler or a veteran variable star observer, you can safely skim over Crater and simply note its two brightest stars — Alpha (α) at magnitude 4. 2 and Gamma (γ), magnitude 4.1. These two stars point almost directly at NGC-3242, which definitely is worth looking for.

Although slightly smaller in area than Crater, Corvus is a rich little constellation worthy of an evening's study. Statistics on its brightest stars show an interesting variety.

Name	Magnitude	Distance (light-years)	Spectral Class
Gamma (γ)	2.6	450	B8
Beta (β)	2.7	110	G5
Delta (δ)	3.0	125	B9
Epsilon (ε)	3.0	140	K3
Alpha (α)	4.1	65	F2
Eta (ζ)	4.4	60	F2

Gamma shines brightest even though it is the most distant, and thus ranks as the powerhouse of the group. Computations show it actually shines 1,200 times more brilliantly than the sun. There seems to be only one family relationship among these six stars, and that is the spectral characteristics and distances of Alpha and Eta. They were once part of a star cluster that has now dispersed, but for some reason these two have not strayed far from each other.

The striking quadrilateral arrangement of the four brightest Corvus stars makes the group easy to recognize and useful as a guide to surrounding star fields. For example, the top two stars point east to Spica while the bottom two direct you eastward to Gamma Hydrae (magnitude 3.0). A line from Gamma Corvi through Beta leads to the northern section of Centaurus — a constellation (regrettably) largely hidden to United States observers.

Our Close-Up zone also includes parts of the straggling Hydra, a relatively barren constellation that does manage a fair number of interesting objects simply because of its size. The section of Hydra seen here is probably its richest region. Unfortunately for observers in northern states and Canada, the objects in Hydra are well down toward the southern horizon.

When we combined the old Star Dome and Constellation Close-up sections into this one department last January, we asked for your comments. Since then we have received dozens of letters lauding the new format. But there was one thing you seemed to miss — the Table of Objects. We are pleased to comply by returning that feature with this issue. The editors would like to take this opportunity to thank those of you who take time to express your opinions about the magazine. We will continue to evolve in response to reader requests.

EYEPIECE IMPRESSIONS

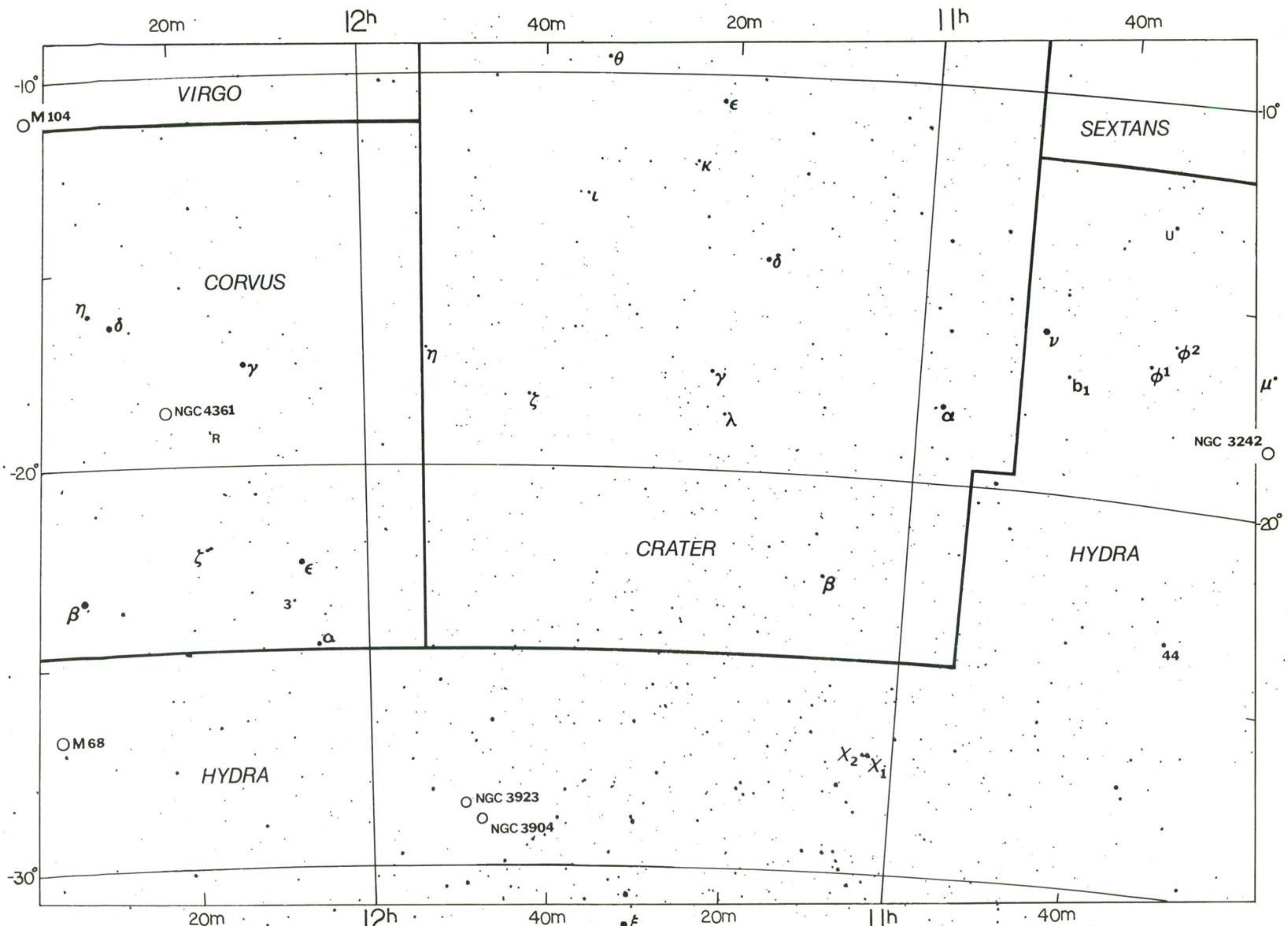
NGC-3242

The expanse of sky lying south of the celestial equator is often neglected by today's astronomy enthusiasts, due at least in part to the fact that much of this zone is immersed horizon glow and general atmospheric pollution. And yet many unsuspected wonders quietly await the observer who will venture into these regions. The balmy evenings of late spring are ideal for such explorations, and the sights encountered along the way will amply reward the time and effort spent.

A striking example of this neglect is the virtually forgotten planetary nebula NGC-3242 in Hydra, situated just two degrees south of fourth magnitude Mu (μ). Here we find what is perhaps the finest example of its class after the famed Ring nebula in Lyra. Large (40 by 35 seconds in extent) and bright (ninth magnitude), this celestial blue "egg" is obvious in a three inch refractor at just 45 power. At such low magnification, most planetaries are indistinguishable from stars.

Having an apparent diameter nearly that of the planet Jupiter, many of the classic observers of the past have compared the two objects in their descriptions. Olcott tells us, "It will be seen like a pale blue disk, like the ghost of Jupiter," — while Admiral Smyth even goes so far as to say that NGC-3242 "resembles Jupiter in size, equable light, and color." On the last point we have to disagree with the Admiral, for this planetary shines with an intense blue glow.

This high surface brightness allows the use of considerable magnification. Even 75 to 100 power on a four inch telescope reveals hints of internal detail including a bright nucleus. The view in eight inch and larger instruments is simply thrilling. Using his homemade 10 inch reflector, Barns described it as "one of the most amazing of the planetary class — elliptical, pale steely blue... with... star nucleus framed in double rings." Internal rings are also mentioned by Webb as "...two semicircular arches of stars, forming a sparkling ring, with one star on the hazy ground of the center."

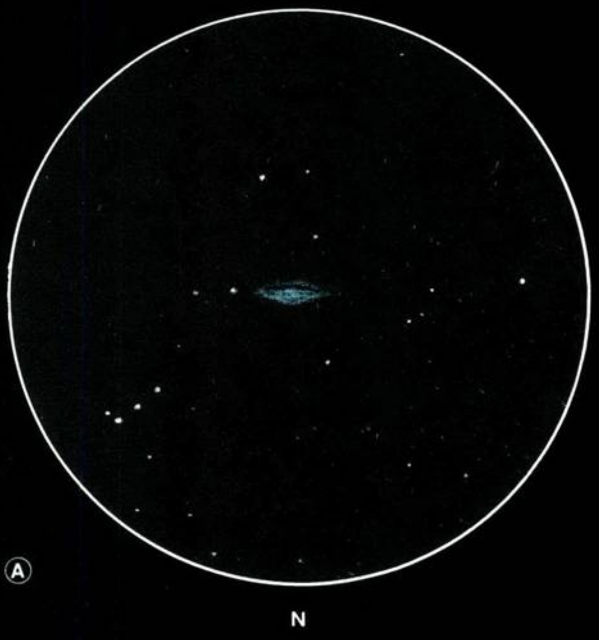

20m
12h
40m
20m
11h
40m
-10°
VIRGO
M104
SEXTANS
θ
ε
κ
ι
δ
CORVUS
η
δ
γ
η
ζ
γ
λ
α
ν
b1
φ1
φ2
μ
U
NGC 4361
R
NGC 3242
-20°
20°
CRATER
HYDRA
ζ
ε
β
3
β
α
44
M68
HYDRA
χ_2 χ_1
NGC 3923
NGC 3904
-30°
20m
12h
40m
20m
11h
40m

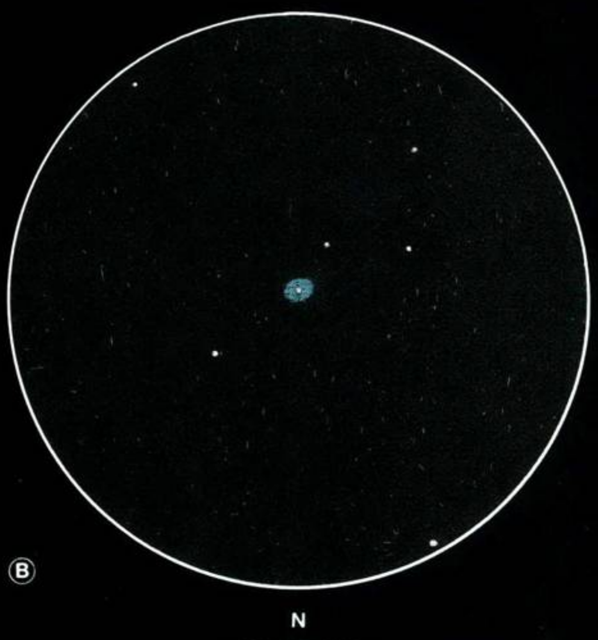
The nucleus itself has had an unusual history and merits careful watching by well-equipped observers. Current catalogs list an 11th magnitude central star. However the famed observer W. H. Pickering, using an 11 inch refractor in Jamaica, recorded that "In 1892, the writer observed that it had a bright star in its center. This has now (1917) disappeared." Webb's description was written prior to 1892, while Barns observed after 1917 — both observers called attention to the star. Apparently it vanished and then reappeared! Adding to the enigma is the fact that the present form of the nucleus is that of a bright knot rather than a sharply defined star.

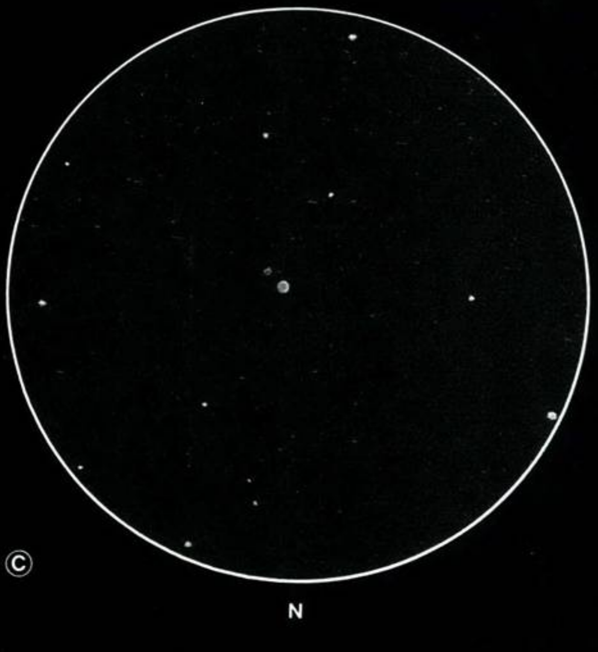
U Hydrae

Another showpiece of this region lies to the north of NGC-3242, forming the top of an equilateral triangle with Mu (μ) and Nu (ν) Hydrae. This is the intensely red variable star known as U Hydrae. Just visible to the unaided eye, its color is obvious in a 2.4 inch refractor at 30 power and presents a pleasing view on dark nights.

Having a magnitude range from 4.8 to 5.8 (a factor of 2-1/2 times), U's red hue seems deeper when the star is fainter — as is the case with most variable stars. Also, it seems more strongly colored than other stars of its spectral class type N, possibly due to the increased atmospheric absorption at low altitudes.







(A) The giant spiral galaxy M-104, seen nearly edge-on, has a prominent dust lane that is readily visible in moderate sized telescopes. This sketch was made at 45 power with a four inch reflector. The field of view is about one degree.

(B) The rarely observed planetary nebula NGC-3242 is actually an easily distinguished and fascinating object as described in this article. This celestial puff of gas is framed in a 1/2 degree field at 70 power in a four inch reflector.

(C) The finest double star in our close-up area this month is Delta Corvi, a third magnitude star to the unaided eye but a pretty pair in the smallest telescopes. This is a four inch reflector view at 45 power.

Sketches by James Mullaney

On nights of high transparency with accompanying poor seeing (image steadiness), U Hydrae takes on the appearance of a flashing buoy riding the serene ocean of night.

M-68

Following the curving body of Hydra south and east beneath the barren outpost of Crater, we come finally to a neat ball of stars just under the "sail" of Corvus. Designated M-68, this celestial beehive is one of the first globular clusters to appear in advance of the coming hordes of such objects that populate the summer sky. Sweeping along a line from Delta (δ) through Beta (β) Corvi, four degrees to the south, a good finder or binoculars will show this object as a fuzzy glow. Nearby is a fifth magnitude star which serves to mark the approximate location of M-68.

Most descriptions of this cluster are very terse, again indicating that little time is spent in observing at these declinations. Barns calls M-68 "imposing", and Webb simply notes "well resolved". These impressions were obtained with 10 inch and 9 inch reflectors, respectively, and indicate that such apertures are necessary for a good view. As sparcely concentrated as globulars are, even a four inch telescope at moderate powers can achieve resolution when seeing is good. Some three minutes in diameter, M-68 has an integrated or total magnitude equal to that of an eighth magnitude star seen out of focus. Distance estimates place this cluster at 46,000 light-years away — twice as far as M-13 in Hercules.

NGC-4361

North of M-68, within the quadrangle of Corvus itself, lies a very real challenge to the deep sky enthusiast. This is the planetary nebula NGC-4361. Although of the same apparent size as the Ring nebula (about 80 seconds), it is much fainter at magnitude 11 and also much lower in the sky, making it a difficult object in amateur instruments.

The nebula lies directly on a line joining Delta (δ) and Epsilon (ε), and very near its intersection with a line connecting Gamma (γ) and Beta (β). Careful sweeping of this area with a six inch or eight inch reflector at 75 to 100 power will reveal it looking much like a faint stain against the sky background. Catching such an elusive prey is certainly a rewarding experience — well worth the time spent. In this case, we need not worry about straying too far afield for our hunting ground is fenced in by the four bright stars of Corvus.

Delta (δ) Corvi

For a refreshing change after an eyestraining session in search of NGC-4361, point your telescope to Delta, the top left corner star of Corvus. You will be greeted by a pleasing sight — a third magnitude yellow-white star attended by an eighth magnitude companion of a lilac or reddish-purple hue, some 24 seconds distant. Here is a subject for even the smallest of instruments!

In four inch and larger telescopes, the small star's unusual color is quite intense, presenting a fine contrast with the primary. In viewing the contrasting hues of double stars like Delta, we are led to wonder about the conditions of lighting and color on any planets which may be present. Bright yellow sunlight might alternate with a pale purple glow flooding the nighttime landscape of a hypothetical world orbiting Delta. There would be no double sun effect, though, because the two stars are separated by about 1,000 times the Earth-sun distance.

The two stars together form what is known as a *common proper motion* (cpm) pair, which means that both suns are drifting through space at the same speed and in the same direction. Although we have no direct evidence of orbital motion, the two stars are very likely in orbit about each other, making Delta a very long-period binary system.

M-104

Continuing our survey north above Delta Corvi and near the Virgo-Corvus border, we find the famous Sombrero galaxy, M-104. Situated at the corner of a right triangle formed with Spica and Gamma in Virgo, this showpiece can be easily seen in a 2.4 inch (60mm) refractor at 30 power. Greatly aiding its identification are two nearby chains of seventh and eighth magnitude stars, one of which is in the same eyepiece field with the galaxy and points right at it like an arrow!

Appearing as a hazy ellipse six by three minutes in extent, this distance spiral is one of the brightest (8.7 magnitude) and finest objects of its class in the sky. The most unusual and interesting feature about M-104 is the dark band of obscuring matter circling its equatorial region, giving rise to its well-known hatlike shape. Displaced somewhat south of the galaxy's nucleus, this dark cleft can be seen with a four inch telescope at 70 power and is even noticeable at 45 power using averted vision.

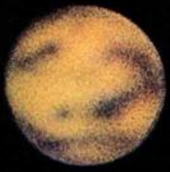
As with other deep sky objects, the most effective and relaxed technique for observing the Sombrero is to place the galaxy at the edge of the eyepiece field and allow Earth's rotation to slowly carry the object across your view. Proper dark-adaptation (at least 15 minutes) and transparent moonless nights will add considerably to the amount of detail that can be seen. To a trained eye using eight inch and larger reflectors, M-104 looks just as good as in its photographs.

Viewed on a mild May evening with stars sparkling overhead and the air filled with the scent of spring, this distant star city evokes much leisurely contemplation. Looking across a gulf of more than 37 million light-years (or 222,000,000,000,000,000,000 miles!), we are able with our feeble eyes and instruments to grasp something of the vastness and majesty of the universe. As has been observed, "In the last analysis, the mind which encompasses the universe is more marvelous than the universe which encompasses the mind...."

Planet Finder

Ⓒ Cere

May	1	15
R.A.	1h55m	2h15m
Dec.	+1°18'	+1°19
Mag.	+8.6	+8.6



Ⓐ Mercury

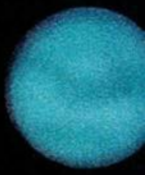
May	1
R.A.	3h30m
Dec.	+20°43'
Mag.	-0.8

Ⓑ Mercury

May	15
R.A.	4h59m
Dec.	+25°07'
Mag.	+0.6

Ⓜ Mars

May	1	15
R.A.	23h08m	23h47m
Dec.	-7°09'	-3°03'
Mag.	+1.1	+1.0



Ⓝ Neptu

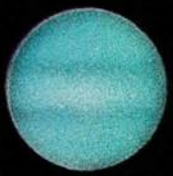
May	15
R.A.	16h3
Dec.	-20°3
Mag.	+7.7

SUN

The sun is within the stippled zone throughout the month. Planets and stars near this area are not easily seen.

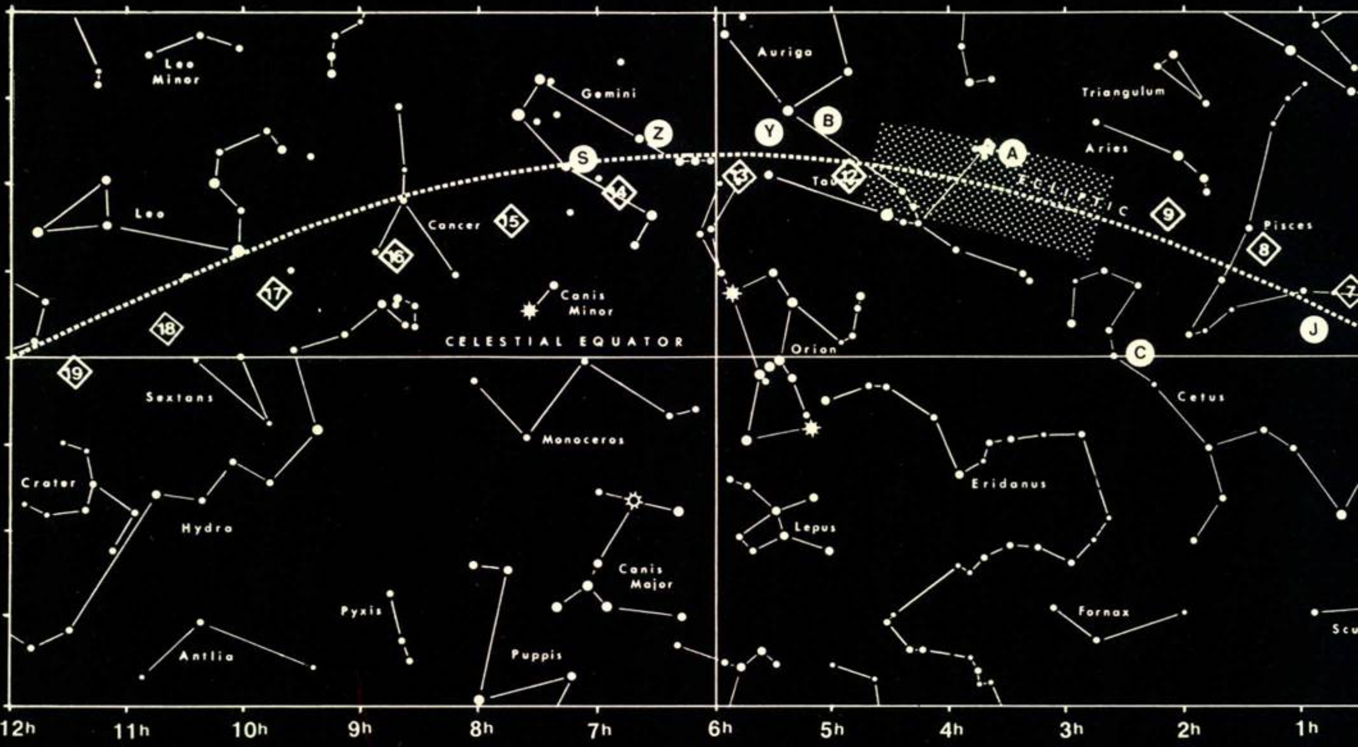
Ⓢ Saturn

May	1	15
R.A.	7h00m	7h06m
Dec.	+22°32'	+22°26'
Mag.	+0.4	+0.4



Ⓤ Uranus

May	15
R.A.	13h50m
Dec.	-10°45'
Mag.	+5.7


Leo Minor
Gemini
Auriga
Triangulum
Aries
Z
Y
B
S
A
Leo
Ta
ECLIPTIC
Cancer
Pisces
Canis Minor
CELESTIAL EQUATOR
Orion
C
J
Sextans
Cetus
Monoceros
Crater
Eridanus
Hydra
Lepus
Canis Major
Pyxis
Fornax
Antlia
Puppis
Scu
7
8
9
12
13
14
15
16
17
18
19
12h
11h
10h
9h
8h
7h
6h
5h
4h
3h
2h
1h

Map by Raymond G. Coutchie

The chart shows the positions of the moon, planets and brightest asteroids for the current month. Letters within the circles correspond to the letters beside each object in the data section above the map. Additional information about each object is given there. R.A. = right ascension and Dec. = declination, the two coordinates used to locate astronomical objects. The general coordinate system is indicated around the edge of the map. Mag. = magnitude, a

May 1975

Ⓥ Vesta

lay	1	15
R.A.	22h45m	23h08m
ec.	+1°20'	+1°19'
lag.	+7.3	+7.3

Ⓙ Jupiter

May	1	15
R.A.	0h40m	0h51m
Dec.	+3°07'	+4°17'
Mag.	-1.6	-1.7

Ⓨ Venus

May	1
R.A.	5h20m
Dec.	+25°15'
Mag.	-3.6

Ⓩ Venus

May	15
R.A.	6h30m
Dec.	+25°45'
Mag.	-3.7

Ⓟ Pluto

May	15
R.A.	12h51m
Dec.	+13°13'
Mag.	+14

First Quarter

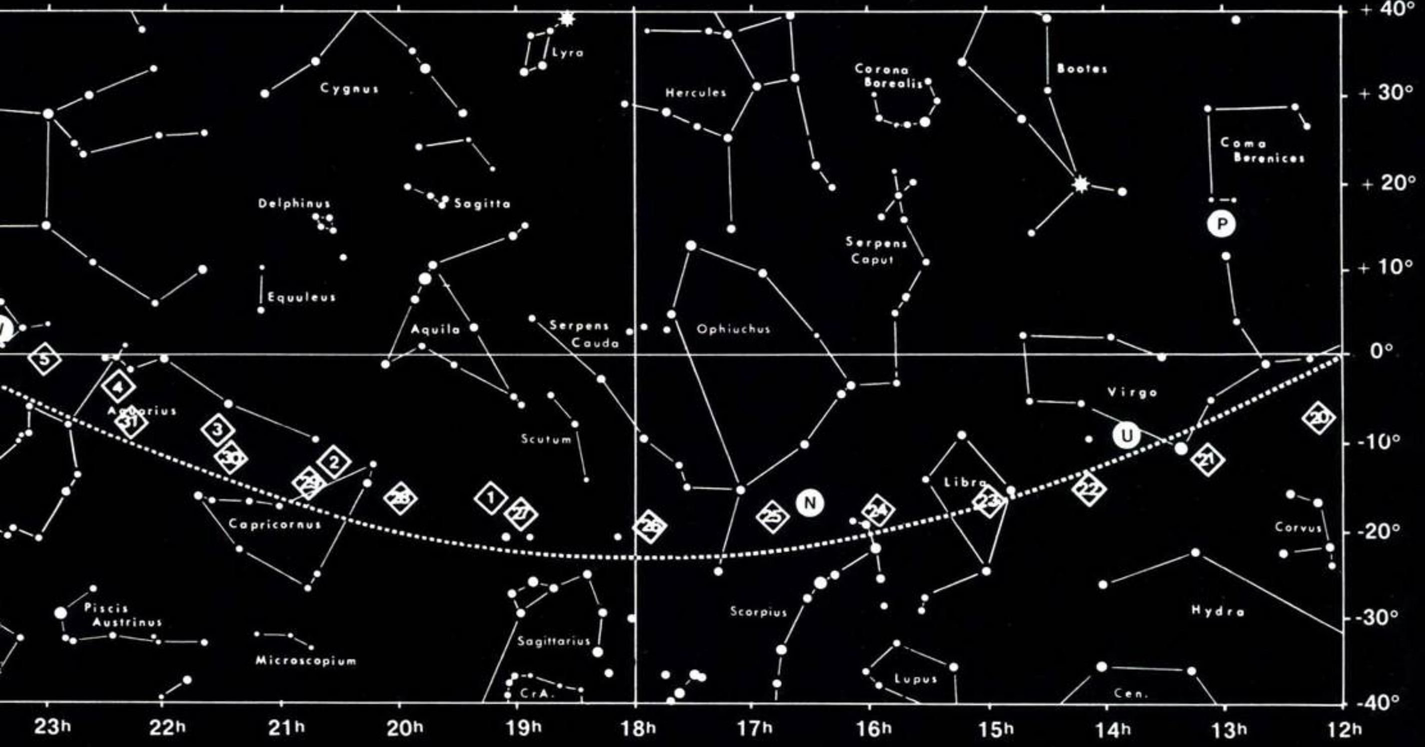
May 18

Full Moon

May 25

Last Quarter

May 3


+40°
+30°
+20°
+10°
0°
-10°
-20°
-30°
-40°
Lyra
Cygnus
Hercules
Corona Borealis
Bootes
Coma Berenices
Delphinus
Sagitta
Serpens Caput
Equuleus
Aquila
Serpens Cauda
Ophiuchus
Aquarius
Scutum
Virgo
Capricornus
Libra
Corvus
Piscis Austrinus
Microscopium
Sagittarius
CrA.
Scorpius
Lupus
Hydra
Cen.
P
U
N
5
4
31
3
30
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23
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20
23h
22h
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20h
19h
18h
17h
16h
15h
14h
13h
12h

Artwork by Victor Costanzo

measurement of the object's brightness. (The minus magnitudes indicate very bright planets.) The diamonds with numbers within them indicate the position of the moon for each day of the month; the numbers correspond to the dates. Positions of the planets are for the 15th of the month except for Mercury and Venus which are shown on both the 1st and 15th. Certain areas of this map and the Star Dome chart overlap each month.

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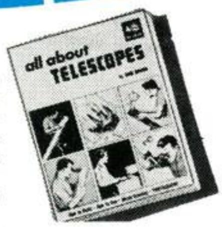

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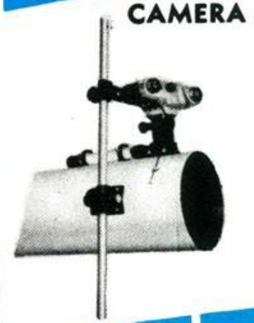

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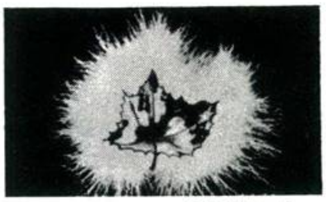

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1. **EXQUISITE OPTICAL SYSTEM INCLUDES f/8 6-INCH PARABOLIC MIRROR** made of **PYREX**-brand glass, accurate to better than ⅛ wave, zircon-quartz coated, and guaranteed to reach the theoretical limits of resolution and definition. Teamed with elliptical diagonal mounted in 4-vane adjustable spider.
2. **NEW DYN-O-MATIC ELECTRIC DRIVE** with smooth self-acting clutch that engages and disengages automatically as you seek different objects. Will not interfere when manual operation is desired. Safety housed case. Plugs into ordinary AC socket.
3. **TWO EYEPIECES:** Achromatic Ramsdens **70X** (18 mm.), **140X** (9 mm.). Also available: **100X** (12.7 mm.), **180X** (7 mm.). Achromatic Ramsdens, $14.95 each; **220X** (6 mm.), **320X** (4 mm.). Orthoscopics, $18.50 each.
4. **SOLID NEW EQUATORIAL MOUNT,** extra-reinforced design to provide pillarlike stability. No annoying side play or wobble. Adjusts easily to any latitude.
5. **SETTING CIRCLES** for both right ascension and declination. Handsomely engraved and finished in fine aluminum.
6. **6 x 30 FINDERSCOPE, ACHROMATIC, COATED,** with accurate cross hairs and fine focus. Durable cast-aluminum bracket with 6 adjusting screws allows positive collimation.
7. **ROTATING TUBE FOR MAXIMUM VERSATILITY AND VIEWING COMFORT.** Solid-cast chrome-finished rings are generous 1″ wide with felt lining. Newly designed construction, with oversized knurled adjusting knobs, affords maximum rigidity and allows quick disassembly and portability, with or without tube.
8. **STRIKINGLY HANDSOME WHITE 50″ BAKELITE TUBE** with porcelainized Duralite finish, durable yet light. Walls are ⅛″ thick, completely insulated and anti-reflective blackened inside.
9. **BRASS RACK-AND-PINION EYEPIECE HOLDER** has precision-cut rack and gear for easier, smoother, more positive focusing. Takes standard 1¼″ oculars, negative or positive.
10. **STRONG, VIBRATION-FREE, ALL-METAL TRIPOD** with easily removable legs. Provides sure, steady support, plus lightweight portability.

Orders for the RV-6 Have Set New Records!

Demand for this fine instrument, so well proved in use, has been soaring, as more and more serious telescope buyers have come to realize, by comparison, what an extraordinary value it is. To keep pace, we hurried along a planned expansion into facilities more than three times as large as before.

We stepped up production as rapidly as we could—but remember, this is a precision, handcrafted instrument, individually built to our exacting standards, and individually guaranteed. In addition, our industry like most others has had to contend with shortages. At times, critical materials have just not been available. In spite of all efforts, order backlogs grew, and we have felt obliged to offer refunds to anyone who did not want to wait. (Very few accepted —which itself is significant.) Today our backlog has been brought down a great deal, though we must still reluctantly keep you waiting a while. Our apologies... but it is comforting to know that when your telescope arrives, it will be in every respect the easy-to-operate, outstanding performer you ordered—an RV-6 Dynascope.

Criterion Manufacturing Co. Dept. AS-30
620 Oakwood Ave., West Hartford, Conn. 06110

☐ Please send me, under your unconditional guarantee, the RV-6 6-inch Dynascope. Payment of plus $15.00 crating charge is enclosed.

☐ Send FREE ILLUSTRATED LITERATURE describing the RV-6 6-inch Dynascope and all the telescopes in the Dynascope line.

☐ Send FREE ILLUSTRATED LITERATURE on your new DYNA-TRACKER™ Variable-Speed Control for RV-6 or other electric-drive telescopes.

Name

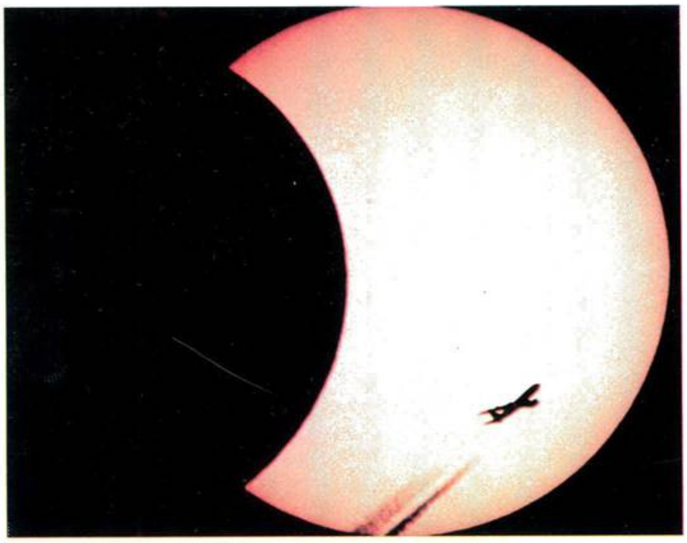
Address

City State Zip

Criterion Manufacturing Co.
620 Oakwood Ave., West Hartford, Conn. 06110
Manufacturers of Quality Optical Instruments

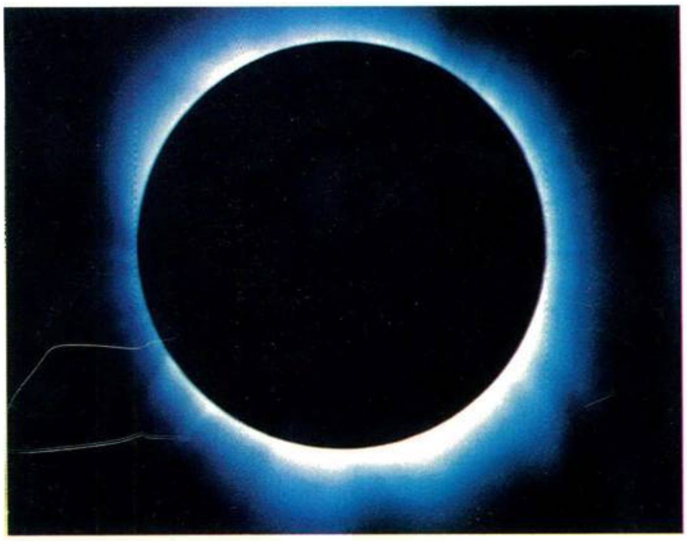
Celestron®

World's Leading Manufacturer
of Schmidt-Cassegrain Optics
for Astronomy, Industry, Education



Above: Contrails swirl behind a jet crossing the partially eclipsed solar disk — Celestron 8 photo.

Below: A crown of light rings the sun in total eclipse — Celestron 5 photo.



World's only complete line of large-aperture, compact-portable telescopes: the prestigious Celestron 14 (left), the super-portable Celestron 5 (center), and the most popular of the Celestron telescopes, the Celestron 8.

Nature Waits for No Man

As far as Nature is concerned, her comets arrive on schedule. Her supernovae blaze up at exactly the right moment. Her lunar and solar eclipses come and go precisely on time.

Unfortunately, however, Nature's timetable is often a secret. No one knows when a supernova will flare up and outshine the star of Bethlehem. No one knows when the lunar crater Aristarchus will start to glow again, or for how long.

And consider this: Halley's Comet is due back in 1986. But suppose it arrives early? Impossible? Perhaps.

Even when Nature's schedule is known, news of celestial events seldom reaches you in time to order and receive a telescope. If you wait until the event is popularized, you won't get your telescope in time.

When Halley's Comet reappears, a flood of stories will be carried in the press and over the air waves. But by then a two-year backlog among telescope manufacturers won't be uncommon.

So why not be ready now? Order your Celestron while a slow period for the economy (and cosmic spectaculars) presents you with an opportunity to purchase at an unprecedented price.

Celestron 5 - $695
(reduced from $750)

LIMITED OFFER

Celestron 8 - $795
(reduced from $965)

"First-Come, First-Served . . . Offer Expires May 31, 1975"

The telescope that has come to be accepted as the number one choice the world over . . . the most coveted, most recommended among serious amateur astronomers, professors of astronomy and planetarium educators, is now available to you at a drastically reduced price for a limited time only.

Since the introduction of the Celestron 8 and the Celestron 5 some years ago, the demand for these fine instruments has always exceeded our production capacity. Each year, orders have typically doubled from the preceding year.

To meet this increased demand, it has been necessary to acquire new manufacturing space, place additional machinery in operation and train new personnel.

Moreover, to keep our delivery times short (we seldom ask our customers to wait more than eight weeks for these telescopes), it has been necessary to predict orders six months in advance. This has required applying a major portion of our working capital toward financing an in-process inventory of telescopes.

Now, because of the economy, orders have leveled off temporarily and we have, nearing completion, a number of Celestron 5 and Celestron 8 telescopes which were begun in anticipation of a continually rising level of orders.

To reconvert this inventory into working capital, we have decided to forego profit on these instruments and offer them at a reduced rate. These telescopes are available on a first-come, first-served basis.

C5, C8 owners: If you haven't received your copy of our new instruction manual, drop us a postcard. No charge, of course.

Celestron Pacific

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